Sci

SCIENCE

4 April 1958

Volume 127, Number 3301

5 - APR - 9
Copy 1958

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

Q1
.S35
2d set

Alfred North Whitehead...on the passion for discovery

"Disinterested scientific curiosity is a passion for an ordered intellectual vision of the connection of events. But the goal of such curiosity is the marriage of action to thought. This essential intervention of action even in abstract science is often overlooked. No man of science wants merely to know. He acquires knowledge to appease his passion for discovery. He does not discover in order to know, he knows in order to discover. The pleasure which art and science can give to toil is the enjoyment which arises from successfully directed intention. Also it is the same pleasure which is yielded to the scientist and to the artist."

—*The Aims of Education, 1917*

THE RAND CORPORATION, SANTA MONICA, CALIFORNIA

A nonprofit organization engaged in research on problems related to national security and the public interest

NOW!

On-the-spot PHOTOMICROGRAPHS

...ready to project in 2 minutes

with the CENCO® Camera Support ...
and the new POLAROID
Transparency System

The spectacular new Polaroid Transparency System now offers you high quality photomicrographs faster, more economically than ever before. Teaming the regular Polaroid® Land Camera with the Cenco Micrography Camera Support, you can immediately photograph objects seen under the microscope for permanent record, and project the finished slide within two minutes. Research workers, students, teachers and amateur photographers now have a means of photographing grain structures of metals and alloys, animal and vegetable tissues, and minute organisms.

While the specimen is still available, the operator knows immediately whether the proper field of view and correct exposure time were obtained. For lecture courses, slides can be produced instantly and projected for classroom study. (Paper prints can be made simply by using the same equipment, but another film.)

The Cenco Micrography Camera Support is custom-designed specifically for use with the Polaroid Land Camera. Height is adjustable to fit any make of microscope. A special viewer, which adjusts to the optical equivalent of the camera, is used to focus microscope—prior to moving camera into position.

Polaroid® Land Projection Film produces finished black and white slides in two sizes: 2¼" x 2¼" and 3¼" x 4", for use in lantern slide projectors. This panchromatic film has speed, range, contrast and latitude to produce high detail photomicrographs. (speed of 1000 daylight —ASA equivalent exposure index)

For further information, write for circular 1208P

No. 65730 Cenco Micrography Camera Support .. $87.50
No. 65735 Polaroid Land Camera $89.75
No. 65737 .... $ 3.49

® by Polaroid Corp., Cambridge, Massachusetts

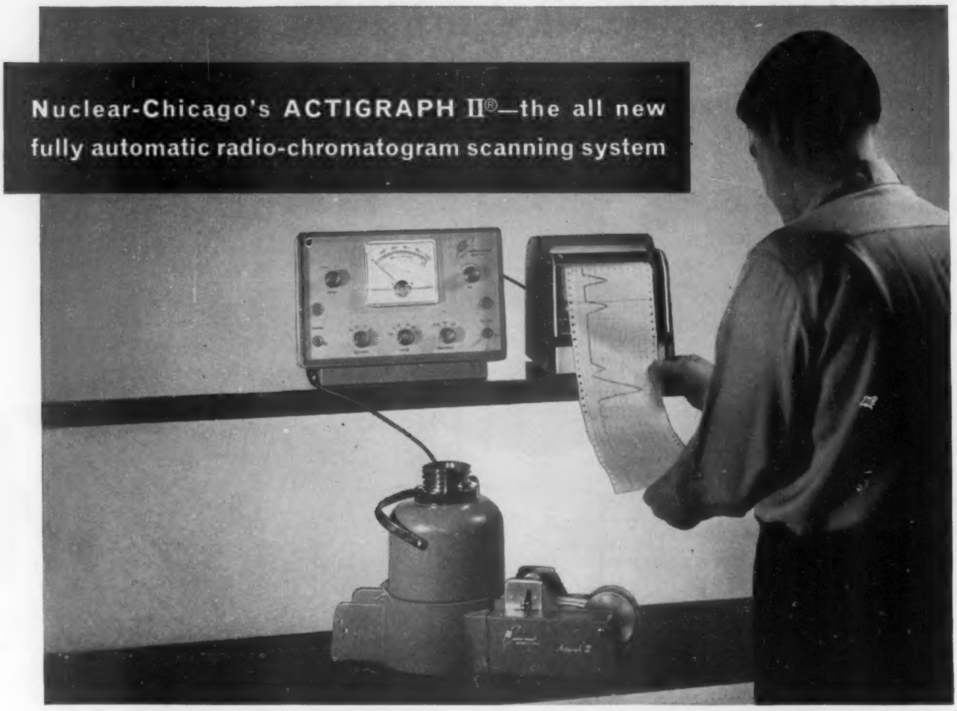
cenco
The most complete line of scientific instruments and laboratory supplies in the world

CENTRAL SCIENTIFIC COMPANY

General Offices and Factory—1718-■ Irving Park Road • Chicago 13, Illinois
Branches and Warehouses—Mountainside, N. J. • Boston • Birmingham
Central Scientific Co. of California—Santa Clara • Los Angeles
Refinery Supply Company—Tulsa • Houston
Central Scientific Co. of Canada, Ltd.—Toronto • Montreal • Vancouver • Ottawa

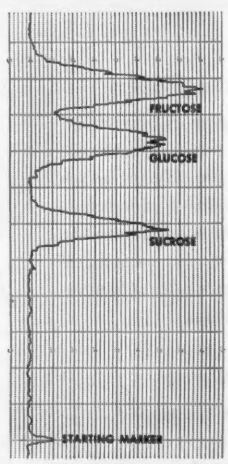
SCIENCE is published weekly by the AAAS, 1515 Massachusetts Ave., NW, Washington 5, D.C. Entered at the Lancaster, Pa., Post Office as second class matter under the act of 3 March 1879. Annual subscriptions: $8.50; foreign postage, $1.50; Canadian postage, 75¢.

a new radioisotope counting system for biological and clinical research



Completed chart can be placed next to strip to directly determine location and intensity of radioactive zones.

The new Actigraph II is a completely redesigned and improved scanning system for recording automatically the position and total activity of separated radioactive zones on a strip chromatogram. Two reels accommodate strips up to 50 feet in length allowing single short strips to be spliced end-to-end for continuous operation without attention. A wide choice of detectors may now be used including G-M tubes, *windowless gas flow counters,* and scintillation detectors. Increased sensitivity is provided through improved geometry. The Actigraph II is available with a wide variety of chart recorders including the new "rectilinear" recorder. Chart and strip speeds are easily synchronized by making identical gear changes. For complete information write us and ask for "Nucleus #14".



Typical radio-chromatogram scan made with Actigraph II

Fine Instruments - Research Quality Radiochemicals

nuclear-chicago
CORPORATION
237 WEST ERIE STREET • CHICAGO 10, ILLINOIS

ANNOUNCING A NEW TEXT!

(Just Ready)

GENERAL ZOOLOGY

by

Villee, Walker & Smith

Sample Chapter Coverage

Chapter 4

CELL METABOLISM 64
- Chemical Reactions 64
- Enzymes 66
- Factors Affecting Enzyme Activity 69
- Respiration and Cellular Energy 71
- The Dynamic State of Protoplasm 74
- Special Types of Metabolism 75

Chapter 13

INTRODUCTION TO THE HIGHER INVERTEBRATES 236
- Evolutionary Relationships of the Sponges 236
- Evolutionary Relationships of the Coelenterates ... 237
- The Evolution of Three Germ Layers 237
- The Evolution of the Coelom 238
- Spiral Cleavage and its Evolutionary Importance .. 239
- The Schizocoelomata and Enterocoelomata 241

A completely new and up-to-date text. Its unique presentation of both vertebrate and invertebrate life emphasizes not merely anatomy, but also habitat, mode of life and role in the biologic community. It is perfectly balanced between the "principles approach" and the "animal types approach"—carefully blending discussions of broad biological principles with a thorough examination of certain representative animals.

General concepts are clearly explained in the beginning of the book. Each invertebrate phylum occupies a separate chapter. A detailed consideration of the frog introduces the vertebrates. Vertebrate morphology and physiology are also presented. Classification of animals conforms to the latest thought in taxonomy.

Features and teaching aids are many, including: 444 instructive illustrations—important terms in bold type—review questions at the end of each chapter—maximum flexibility, which permits you to open your course with either the frog or amoeba—no previous course in biology, chemistry or physics is necessary!

Here is a text which can clearly supply the basic facts to average students, yet give interested students an opportunity to pursue subjects which may be omitted or considered only briefly in the lectures and laboratory.

By Claude A. Villee, Harvard University; Warren F. Walker, Jr., Oberlin College; and Frederick E. Smith, University of Michigan. 877 pages, 6" x 9¼", with 444 illustrations. *New!*

CONTENTS

INTRODUCTION 1

Part I. General Concepts

PROTOPLASM 13
CELLS AND TISSUES 33
CELL METABOLISM 64
PRINCIPLES OF PHYSIOLOGY .. 78
REPRODUCTION 114

Part II. The Animal Kingdom

THE PRINCIPLES OF TAXONOMY 139
THE PHYLUM PROTOZOA 148
THE PHYLUM PORIFERA 172
THE PHYLA COELENTERATA AND CTENOPHERA 181
THE PHYLUM PLATYHELMINTHES 204
THE PHYLA ASCHELMINTHES AND NEMERTEA 220
INTRODUCTION TO THE HIGHER VERTEBRATES 236
THE PHYLUM MOLLUSCA 244
PHYLUM ANNELIDA 267
PHYLUM ARTHROPODA 289
PHYSIOLOGY AND BEHAVIOR OF THE ARTHROPODA 326
MINOR PHYLA 352
THE PHYLA HEMICHORDATA AND ECHINODERMATA 360
THE CHORDATES 383

Part III. The Vertebrate Life and Organization

THE FROG—A REPRESENTATIVE VERTEBRATE 393
A HISTORY OF VERTEBRATES:
FISHES 424
AMPHIBIANS AND REPTILES 446
BIRDS AND MAMMALS 468
PROTECTION, SUPPORT AND MOVEMENT 502
DIGESTION AND RESPIRATION 515
BLOOD AND CIRCULATION ... 537
THE UROGENITAL SYSTEM—EXCRETION AND REPRODUCTION 559
SENSE ORGANS AND NERVOUS COORDINATION 574
THE ENDOCRINE SYSTEM 605
THE DEVELOPMENT OF MAMMALS 637

Part IV. Genetics and Evolution

PRINCIPLES OF HEREDITY 649
GENETICS 669
THE CONCEPT OF EVOLUTION . 695
THE EVIDENCE FOR EVOLUTION 716
THE EVOLUTION OF MAN 738

Part V. Animals & Their Environment

ECOLOGY 753
THE ADAPTATION OF ANIMALS TO THEIR ENVIRONMENT .. 781
PARASITISM 799
CONSERVATION 822
A SYNOPSIS OF THE ANIMAL KINGDOM 831

Gladly Sent to Teachers for Consideration as a Text

W. B. SAUNDERS COMPANY

West Washington Square **Philadelphia 5**

NATURAL AERODYNAMICS

By Dr. R. S. SCORER

Hydrodynamics is presented in terms of the physical concepts of force and vorticity which can be appreciated by anyone who observes clouds, smoke, birds or blown sand. The mathematical equations are given from time to time so that they can be followed up by reference to standard texts, but the treatment is essentially self-contained and not dependent upon the mathematics. It is, therefore, accessible to physicists, meteorologists, entomologists, students of air pollution or undergraduate engineers and mathematicians who do not wish for the moment to go beyond it.

Price $9.00

EXPLORING THE ATMOSPHERE'S FIRST MILE

Edited by HEINZ H. LETTAU and BEN DAVIDSON

Vol. I. Instrumentation and Data Evaluation. Vol. II. Site Description and Data Tabulation. These two volumes contain the accounts of a series of elaborate meteorological experiments performed in open prairie country in Nebraska with the primary objective of studying the profiles of wind, temperature and other meteorological qualities in the lower 2,000 m (atmospheric boundary layer), and the physical soil properties affected by diurnal variations of meteorological elements. The project was conceived and organized by the Geophysics Research Directorate, Cambridge Research Center, Massachusetts.

Price for 2 volumes $20.00

ROCKET EXPLORATION OF THE UPPER ATMOSPHERE

Edited by Dr. R. L. F. BOYD and Dr. M. J. SEATON in consultation with Professor H. S. W. MASSEY

This book is the report of the first major international scientific conference concerned with rocket exploration of the earth's upper atmosphere. It includes up-to-date accounts of recent work on the following problems: techniques used in rocket explorations; pressures, temperatures, and winds in the high atmospheres; the structure of the ionosphere; solar ultra-violet radiations; geomagnetic variations; cosmic rays; related laboratory studies; the theoretical interpretation of the results obtained, and suggestions for further experiments.

Price $15.00

VISTAS IN ASTRONAUTICS

Edited by MORTON ALPERIN and MARVIN STERN. Co-ordinating Editor, HAROLD WOOSTER

This is the proceedings of the First Annual Air Force Office of Scientific Research Astronautics Symposium held in February, 1957, and co-sponsored by the Convair Division of the General Dynamics Corporation. The papers survey the scientific and technological progress of astronautics and indicate the lines of research which need to be emphasized to facilitate future space exploration. None of the material has hitherto been published and, although written by professional men, most of the papers are within the intellectual grasp of the intelligent layman.

Price $15.00

THRESHOLD OF SPACE

Edited by M. ZELIKOFF

This volume contains the papers presented at a conference on chemical aeronomy sponsored by the U.S.A.F. Geophysics Research Directorate. The meeting brought together, on an international scale, the leading investigators in upper atmosphere physics and chemistry, with workers engaged in aerothermochemistry, for the purpose of aiding and clarifying existing theories and in delineating problems yet unsolved.

Price $15.00

THEORETICAL ASTROPHYSICS

Edited by V. A. AMBARTSUMYAN. Translated from the Russian by J. B. SYKES

The first three parts, occupying two-thirds of this book, are by E. M. Mustel', and comprise the theory of the continuous spectrum, the theory of absorption lines, and the physics of the sun. The theory of radiative equilibrium is fully discussed, as well as the structure of the photospheres of stars of various spectral classes, and the deviations from thermodynamic equilibrium in stellar photospheres. Line contours and their interpretation, and curves of growth, receive detailed treatment. Sunspots, prominences, the chromosphere, and the corona have each a chapter to themselves, and the same is true of solar electrodynamics. In parts IV, V, and VI, V. V. Sobolev deals with planetary nebulae, novae, and stars with emission lines in their spectra. The physical state of matter in these objects is carefully elucidated, as well as the mechanism of their radiation. Part VII, by A. B. Severnyi, is concerned with the internal structure of the stars, and the book concludes with two parts by the editor himself; one deals with the scattering of light in planetary atmospheres, and the other with interstellar matter. The 183 references include many recent and little-known Russian works in astrophysics.

Price $22.50

Write for fully descriptive leaflets

PERGAMON PRESS NEW YORK LONDON PARIS LOS ANGELES

122 East 55th Street, New York 22, N.Y. — 4 & 5 Fitzroy Square, London W.1.

4 April 1958, Volume 127, Number 3301

SCIENCE

AMERICAN ASSOCIATION
FOR THE
ADVANCEMENT OF SCIENCE

Board of Directors

WALLACE R. BRODE, *President*
PAUL E. KLOPSTEG, *President Elect*
LAURENCE H. SNYDER, *Retiring President*
PAUL M. GROSS
GEORGE R. HARRISON
CHAUNCEY D. LEAKE
MARGARET MEAD
THOMAS PARK
MINA REES
WILLIAM W. RUBEY
ALAN T. WATERMAN
PAUL A. SCHERER, *Treasurer*
DAEL WOLFLE, *Executive Officer*

DAEL WOLFLE, *Executive Officer*
GRAHAM DUSHANE, *Editor*
JOSEPH TURNER, *Assistant Editor*
ROBERT V. ORMES, *Assistant Editor*

Editorial Board

WALLACE R. BRODE
BENTLEY GLASS
KARL LARK-HOROVITZ
EDWIN M. LERNER
WILLIAM L. STRAUS, JR.
EDWARD L. TATUM

Editorial Staff

MARY L. CRABILL, SARAH S. DEES, LUCILLE GUINARD, NANCY S. HAMILTON, OLIVER W. HEATWOLE, NANCY L. JACKSON, YUKIE KOZAI, ELLEN E. MURPHY, BETHSABE PEDERSEN, MADELINE SCHNEIDER, JACQUELYN VOLLMER, MARIA R. WOLSAK

EARL J. SCHERAGO, *Advertising Representative*

SCIENCE, which is now combined with THE SCIENTIFIC MONTHLY, is published each Friday by the American Association for the Advancement of Science at Business Press, Lancaster, Pa. The joint journal is published in the SCIENCE format. Entered at the Lancaster, Pa., Post Office as second class matter under the Act of 3 March 1879. SCIENCE is indexed in the *Reader's Guide to Periodical Literature.*

Editorial and personnel-placement correspondence should be addressed to SCIENCE, 1515 Massachusetts Ave., NW, Washington 5, D.C. Manuscripts should be typed with double spacing and submitted in duplicate. The AAAS assumes no responsibility for the safety of manuscripts or for the opinions expressed by contributors. For detailed suggestions on the preparation of manuscripts, book reviews, and illustrations, see *Science* 125, 16 (4 Jan. 1957).

Display-advertising correspondence should be addressed to SCIENCE, Room 740, 11 West 42 St., New York 36, N.Y.

Change of address notification should be sent to 1515 Massachusetts Ave., NW, Washington 5, D.C., 4 weeks in advance. If possible, furnish an address stencil label from a recent issue. Be sure to give both old and new addresses, including zone numbers, if any.

Annual subscriptions: $8.50; foreign postage, $1.50; Canadian postage, 75¢. Single copies, 35¢. Cable address: Advancesci, Washington.

Radiation and Public Health

As testing of nuclear weapons continues and as more nuclear reactors come into operation, the need to answer questions about the effects of radiation upon health and longevity will become more urgent. Up until now, the primary responsibility for the control and measurement of atomic radiation has been in the hands of the Atomic Energy Commission, although the Public Health Service has played an ancillary role.

The Atomic Energy Commission has had a twofold obligation: to develop and test atomic weapons and reactors and to guard its own workers and the public against excessive doses of radiation. As many people have pointed out, this double function entails a potential conflict of interest, a conflict between the need for testing and the need for keeping the exposure to a minimum. Accordingly, it is noteworthy that the Public Health Service is taking steps to play a larger part in the field of radiation. The service has appointed a National Advisory Committee on Radiation and has asked for an appropriation of $608,000 for its radiological health work—an increase of 50 percent over its appropriation for the current year.

This appropriation will, if granted, permit a moderate expansion in the service's several programs: development of standardized instruments for radiation measurement and analysis; training of radiation health officers for the states; help for medical schools and departments and schools of public health in the training of people in biophysics and public health engineering; measurement of fallout (a network of more than 40 stations for collecting air samples is now in operation); and measurements of radioactivity in samples of milk, food, and water.

This expansion will supplement, rather than replace or compete with, the similar activities of the Atomic Energy Commission. It represents a clear recognition of radiation as a potential public health problem, and it has the merit of relieving the AEC of a part of its responsibility for public health. But, more important, the move will provide an independent source of information about the levels of radiation, and this information will be appraised primarily from the standpoint of public health rather than from the standpoint of weapon development.

The increased interest of the Public Health Service cannot be expected to provide quick answers to the disputed—and highly important—question of whether there is or is not a threshold to low doses of radiation, but the service can be expected to incline to the view that the wise course is to assume that even low doses may be harmful. It may further be expected to aid the states in following the dictum in National Bureau of Standards Handbook 59, which urges "that exposures to radiation be kept at the lowest practicable level in all cases." Through its Bureau of State Services, the service can also be expected to encourage the states to pass legislation that will ensure that the new and more rigorous standards for dosage proposed by the National Committee on Radiation Protection and Measurement will become nationwide.

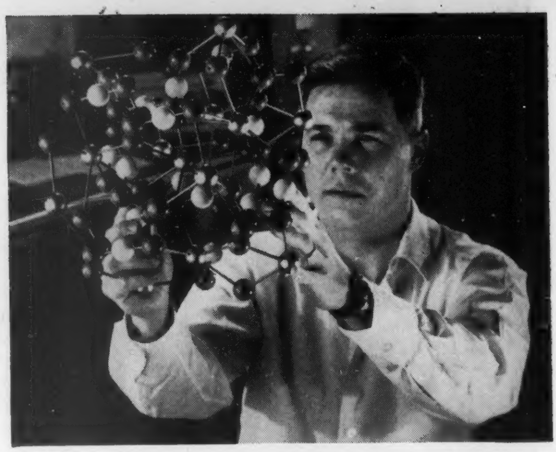
During this interim period when knowledge of radiation effects at low doses is incomplete, the Public Health Service has an important role to play. The importance of its role will be no less when adequate knowledge becomes available. We trust that Congress will approve the modest budget request that will permit the service to do the job that ought to be done. —G.DuS.

SYMBOL

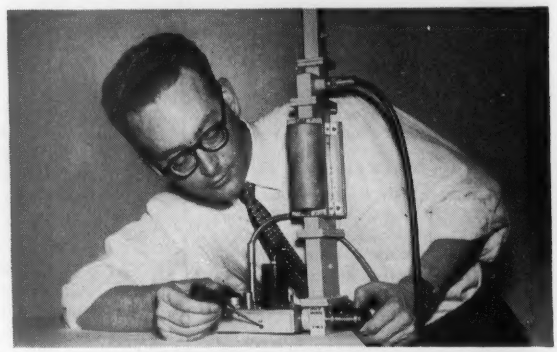
OF A POWERFUL FORCE

The question mark symbolizes man's inquiring spirit. And nowhere is this spirit cultivated with more enthusiasm than at Bell Telephone Laboratories where, through vigorous research and development, it constantly works to improve electrical communications and also to help national defense in essential military programs.

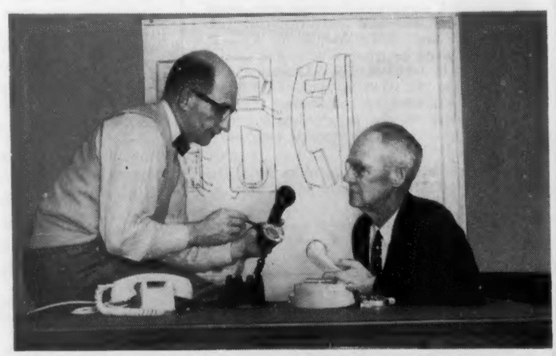
More than 3000 professional scientists and engineers at Bell Telephone Laboratories are exploring, inventing and developing in many fields: chemistry, mathematics and physics, metallurgy, mechanical engineering, electronics and others. You see the successful results achieved by this organization of inquisitive and highly trained minds in the nationwide telephone system that serves you.



Dr. Walter Brown, physics graduate of Duke and Harvard Universities, bombards crystalline solids with one-million-volt electrons to study the nature of simple defects in crystals. Objective: new knowledge which may help improve transistors and other solid state devices for new and better telephone and military systems.



Peter Sandsmark, from Polytechnic Institute of Brooklyn, and his fellow electrical engineers develop a new microwave radio relay system able to transmit three times as much information as any existing system. Objective: more and better coast-to-coast transmission for telephone conversations and network television.



Bill Whidden, from Polytechnic Institute of Brooklyn, and George Porter, from Georgetown College, study new experimental telephone instruments designed to explore customer interest and demand. Objective: to make your future telephone ever more convenient and useful.

BELL TELEPHONE LABORATORIES

WORLD CENTER OF COMMUNICATIONS RESEARCH AND DEVELOPMENT

4 April 1958, Volume 127, Number 3301 SCIENCE

Recent Advances in Rational Mechanics

The search for underlying concepts and strict mathematical proof deepens our understanding of mechanics.

C. Truesdell

I begin by answering the question that will occur to many a reader upon seeing the title: What is rational mechanics? It is difficult to define rational mechanics, but no more so than to define chemistry or physics or mathematics. However, a chemist writing a survey of his field is not expected to begin by defining chemistry. The difference is that in the United States, at least, rational mechanics is not a recognized science. Indeed, there are some who disbelieve in its existence (*1*).

Relation to Other Disciplines

First, *rational mechanics is a part of mathematics* (*2*). It is a mathematical science, and in its relation to experience, intuition, abstraction, and everyday life it does not differ in essence from other branches of mathematics. There is no need to offer here a general defense for mathematics; it should also be unnecessary to point out that mathematics, however abstract and however precise, is a science of *experience*, for experience is not confined to the gross senses. Also, the human mind can experience, and we need not be so naive as to see in an oscilloscope an instrument more precise than the brain. The experiential basis of the sciences is not limited to laboratory experiment.

That rational mechanics grew out of practical mechanics and cooperated with it, if sometimes unwittingly, to produce applied mechanics and mechanical engineering is obvious. In writing the first treatise on rational mechanics, Isaac Newton (*3*) established its standard of mathematical rigor as precisely that of geometry. Not always has this standard been maintained, but today, as in 1687, it remains the ideal. Newton's comparison with geometry is enlightening, for geometry, too, grew from physical experience. To those who scoff at geometry for its precise calculations when all measurements are subject to error, the geometer for millenia has replied: Geometry is mental, not instrumental.

The analogy to geometry is a good one. That rational mechanics speaks not only of space and time but also of mass, force, and energy does not make it any less precise. Since it deals with a greater number of physical concepts than does geometry, its applications to physical problems may be expected to be more frequent and more far-reaching, but physical applications are not its objective.

But does not rational mechanics deal with quantities of physical experience? Indeed it does; so does geometry, for lengths, surfaces, and volumes are equally related to physical experience. The geometer may visualize a surface in terms of a twisted strip of paper, as in mechanics we may think of a force as a manual push, but whatever these motivations, the symbols in the equations of geometry and mechanics are precisely defined mathematical quantities. Origin in broader experience should make mechanics more interesting but not any less exact.

Might not the same be said of any part of theoretical physics? Indeed, it might; each discipline couched in mathematical symbols is ultimately susceptible of independent mathematical existence. In his famous list of problems for this century to solve, David Hilbert (*4*) included that of forming a set of axioms for mechanics, but this problem, like all those he proposed concerning the relation between mathematics and physical experience, has been neglected by mathematicians. Some of the older parts of physics are well on the way toward fully mathematical treatment, but they lie outside my scope.

Finally, does not the emergence of rational mechanics as a purely mathematical discipline imply that we have the freedom to invent new laws of mechanics as the geometers invent new spaces? In fact, the geometers are not so wildly speculative as might appear; their inventions usually arise from some experiential need, though not always one easy to explain to laymen. Purely mathematical theories of space have been in existence at least 2500 years, while in mechanics, with some exceptions, we have a tradition of only four or five hundred years, and the rational mechanics of materials, where most modern researches occur, is little over three hundred years old. The properties of mechanical laws most immediate to our experience are not nearly so well explored as are the properties of the space most immediate to our experience. Moreover, mechanics is enormously more complicated than geometry. The ordinary system of mechanical laws continues to offer us mysteries and challenges. While indeed we have the liberty

Dr. Truesdell is professor of mathematics at Indiana University, Bloomington. This article follows closely the Sigma Xi initiation lecture delivered on 16 May 1956 at the State University of Iowa, Iowa City. It has not proved feasible to mention some very considerable advances made since that date.

to explore other mechanical laws, usually we do not choose to exercise this liberty except in the limited and sober way I will explain later.

That rational mechanics is a mathematical science does not mean that its standard is one of mathematical difficulty. Indeed, some great researches in rational mechanics are difficult and intricate, but others are simple. An innovation that is simple and easy to understand is especially prized. The problems are set by the subject; hard or easy, they must be solved, and their mathematical difficulty is just as much an incidental as is their physical application. After all, in this, rational mechanics is not different from other parts of mathematics, for only to the novice is the seeming complexity or difficulty of a mathematical science a measure of its level.

Is rational mechanics a part of pure mathematics? To most mathematicians today, pure mathematics means topology, abstract algebra, or analysis in abstract spaces. These, most certainly, rational mechanics makes no attempt to imitate. While in spirit it is nearest to geometry, its problems, its aims, and its methods bear little evident similarity to those of other parts of mathematics. A theorem in topology is not evaluated in terms of its bearing on the theory of numbers. It is equally ridiculous, though unfortunately not infrequent, to disparage theorems in rational mechanics when they do not also contribute to the more popular branches of pure mathematics.

Is rational mechanics a part of applied mathematics? Most certainly not. While in some cases known mathematical techniques can be used to solve new problems in rational mechanics, in other cases new mathematics must be invented. It would be as misleading to claim that each achievement in rational mechanics has brought new light to other mathematical domains as to claim the opposite, that rational mechanics is a mere reflection from known parts of pure mathematics. It is a mistake to raise the issue of applied versus pure mathematics. Indeed, it is not the aim of rational mechanics to produce methods or results that rate per se as "new" in other parts of mathematics; neither is its aim to avoid them. Equally, it is not the aim of rational mechanics to produce applications, whether to physics, to engineering, or to other parts of mathematics; neither is its aim to avoid them. *Rational mechanics is an independent branch of mathematics.* When a research in rational mechanics predicts a new physical phenomenon or produces a new analytical method, as occasionally happens, this is so much the better. But such by-products, while very welcome luxuries, are not essential. Rational mechanics, like every other distinct science, has its own aims, its own standards, its own independent problems.

Role of Rational Mechanics

There is widespread belief that in physics the basic equations governing physical phenomena are established and then it is the duty of the mathematician, or the applied mathematician, to solve them. When this view is imposed upon mechanics, we are driven to conclude that the basic equations of mechanics are in the textbooks on classical physics and all that is left is for analysts to solve them, for engineers to apply them. This leaves no place at all for rational mechanics, since rational mechanics rarely concerns itself with theorems of existence and uniqueness or with calculation of numerical answers. While such a simple cooperative division of responsibilities between mathematician and physicist may be ideal, it is unreal. Surely we may admit that biologists study biology because they prefer it to physics; thus, that physicists nowadays study nuclear physics rather than classical mechanics need not imply that classical mechanics is a dead field, but may be explained on more subjective grounds, less unflattering to those persons who do cultivate mechanics. (In simple fact, mathematicians who study mechanics today have rejected older views and have formulated the subject afresh; a part of their work has included discovery of new basic equations defining and explaining new classes of physical phenomena.) Moreover, we often hear complaints from the physicists that mathematicians study the wrong problems, neglecting those the physicists have set and pursuing, instead, flights of their own imagination. Mathematicians readily admit this charge. But if the mathematicians have failed so miserably in their half of the ideal bargain, it would be unjust to expect the other end to be supported in full. Finally, the historical fact is otherwise: The great achievements in rational mechanics of two centuries ago, now imbedded in our instruction as "classical," were wrought by a small group of persons who, calling themselves "geometers," pursued the mathematical properties of their equa-

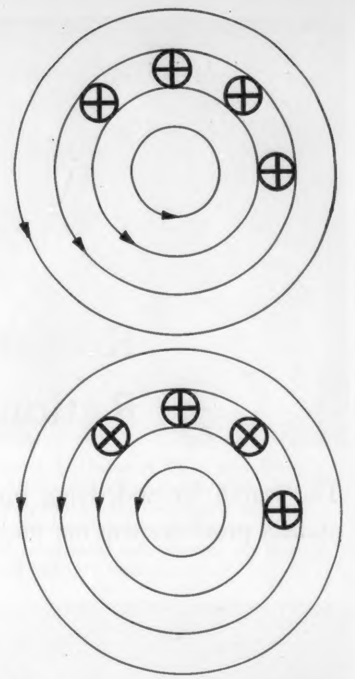


Fig. 2. (Top) vorticity zero; (bottom) vorticity not zero. In both cases, the circular paths of the fluid particles are the same. However, in the case shown in the top diagram, there is no spin, while in the case shown in the bottom diagram, the spin is the same as if the fluid were a rigid wheel.

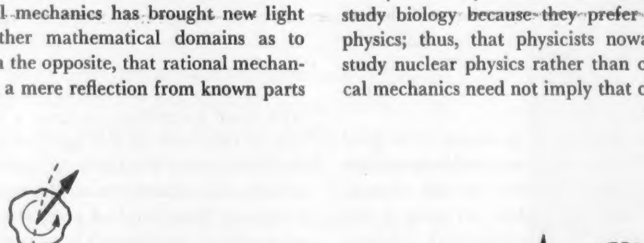


Fig. 1. Spin or "vorticity" of a fluid particle.

tions as vigorously as they pursued the mechanical principles the equations embody. That mechanics has its experimental side is obvious, but the creators of the mechanics we learn today in physics courses resolutely and most openly refused to consider mechanics an experimental science. Had our forebears approached mechanics in the style and spirit often recommended nowadays as being "the scientific method," what today we call "classical mechanics" would have lain undiscovered.

Why then is rational mechanics so unfamiliar today? The term is not new. From Newton's generation until our grandfathers' time, it was in fairly common use. The great American physicist Willard Gibbs (*5*) described his book on statistical mechanics as a contribution to rational mechanics. In several countries of Europe, where academic tradition was fixed earlier, each university has its chair of rational mechanics. The neglect of rational mechanics must be laid to fashion. In this country, especially, about fifty years ago the main course of physics turned to the structure of matter; of mathematics, to abstract collections. Since matter is made up of many small particles, it is natural to expect that understanding of the physics of these particles will lead to understanding of the behavior of ordinary materials. Since the collections of ordinary experience are very special cases of the abstract collections encountered in the mathematics of the last fifty years, it is natural to expect that the new mathematics will explain ordinary phenomena. As is now well known, both these expectations are ideal, not real. The physics and the mathematics of the last fifty years have led to very absorbing developments of their own, but they have not brought us appreciably nearer to mastery of the basic problems of mechanics—for example, to the principles governing failure of metals under load or to solution of the equations which describe this phenomenon. It would be wrong to condemn the last half century for failure to solve the problems it did not really attempt. But the basic problems of mechanics remain, and they are being attacked again. It is some of the brilliant successes of the past decade that I wish to describe here. I say the past decade, but the list of references in a modern article on mechanics is likely to begin with some studies fifty or more years old and then skip to the last six or eight years. With relatively little injustice the discussion that follows could be presented as a summary of progress in the 20th century.

I have said that rational mechanics is a branch of mathematics with its own objective and that this objective is confined neither to the existence theorems typical of the theory of differential equations nor to the calculation of numerical answers for comparison with experiment. Rather, the objective is to *understand* mechanics. Understanding, after all, is the objective of every branch of mathematics. The measure of understanding in any field is partly aesthetic, and it is difficult to explain in general terms what a mathematician means when he says he understands or does not understand a given subject.

Fluid Motion

After these preliminaries, it is best to enter into cases. Let us begin with an old research whose value and quality are uncontestable, because from such an example one can most readily see the kind of result that is prized. No one example can illustrate every possible excellence in rational mechanics, but I select a single classic specimen before passing on to the most recent work.

In a fluid motion, each small part of the fluid may be considered as a body in motion. Such a body may or may not be spinning. If it is spinning, it spins about an axis at a definite rate, and thus its

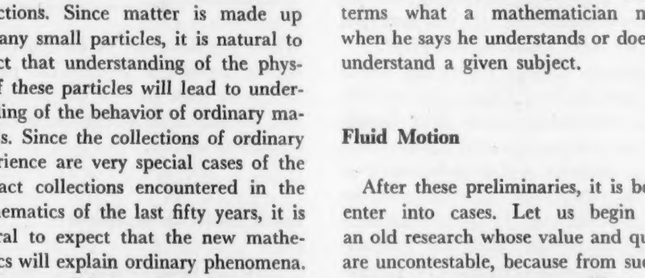


Fig. 3. (Left) vorticity field; (right) vortex lines.

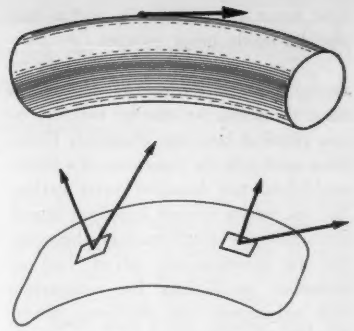


Fig. 4. (Top) vortex tube; (bottom) strength of vortex tube.

spin may be represented by an arrow (Fig. 1). The arrow, which points along the axis of spin and has length equal to the angular speed, is the "vorticity." In one fluid motion different particles may have different vorticities, and the vorticity of a given particle may change as the particle moves. On the surface of a fluid, the vorticity may be observed by following a cork marked with a cross (Fig. 2). If the arms of the cross do not rotate, the vorticity is zero; if they do rotate, there is vorticity. Now the theory of fluid motions in which the vorticity is zero is mathematically much easier than that for the general case, when the particles are spinning. While the case of no spin is appropriate to some applications, particularly for waves on water and for aeronautics, in other cases it is not. For example, without vorticity we could not have the variety of winds actually observed. For a century after the discovery of the fundamental equations for ideal fluids, the nature of spinning motions remained mysterious.

In 1858 an entirely new approach was created by Hermann von Helmholtz (*6*). At each point of the spinning motion, draw the arrow representing vorticity (Fig. 3). Then connect these arrows by curves tangent to them. Such curves are called "vortex lines." If we drop a loop in the fluid, the vortex lines through it will sweep out a tube, called a "vortex tube" (Fig. 4). At a given cross section, project the vorticity upon the direction normal to the surface and then add together these projections at each point of the cross section. The resulting quantity is called the "strength" of the vortex tube at that section. After introducing these new ideas, Helmholtz proved three great theorems about them:

1) The strength of each vortex tube is the same at all cross sections.

2) A fluid particle outside a vortex

tube never crosses into it, and a fluid particle inside never escapes.

3) The strength of the vortex tube remains constant during its motion. In these theorems, we observe that (i) no new physical laws are proposed; Helmholtz used only the equations of a theory established one hundred years earlier; (ii) the results are not based on experiment but are mathematical theorems; (iii) no equations are solved; (iv) no numerical predictions for comparison with experiment are obtained. Nevertheless, these theorems are universally accepted masterpieces of hydrodynamics. In publishing them, Helmholtz remarked that while complete solutions of the problems to which they are related remained possible only in a few of the simplest cases, his theorems made the entire class of these motions "approachable in concept." I think this is what we mean by saying we "understand" a subject mathematically. Understanding is just what Helmholtz' theorems give us. We picture the entire fluid composed of vortex tubes; as the motion proceeds, these tubes may be bent and twisted every which way, yet they continue to separate the fluid into distinct parts. Moreover, the strength of a tube is a measure of the amount of spin within it, and each tube preserves its strength unaltered as the tube itself is transported and deformed. That is, if the fluid spins faster, the tube must shorten, while if the spin decreases, the tube must stretch. Spin once started can never be lost entirely, nor can spin be created in a particle that was not initially spinning. While Helmholtz' theorems do not solve any special problem, they have proved treasures in subsequent study of spinning motions. They are taught in every beginning course on the mechanics of fluids. While they do not explain the phenomena of turbulence or atmospheric winds, they furnish tools that are used habitually by every student of those fields. In looking back on the theorems of Helmholtz, in addition to some qualities peculiar to them alone, we see also two that are necessary for any great work in rational mechanics: (i) new *concepts*, and (ii) strict mathematical *proof*.

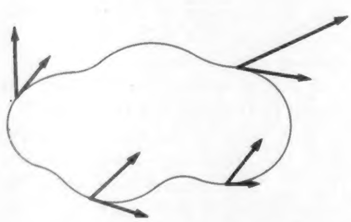


Fig. 5. Circulation of a loop.

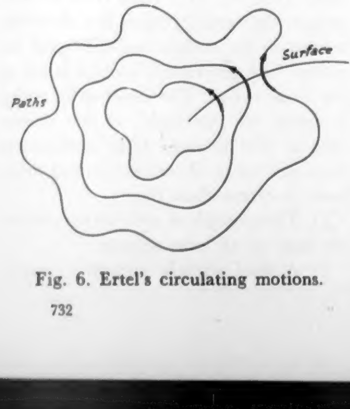


Fig. 6. Ertel's circulating motions.

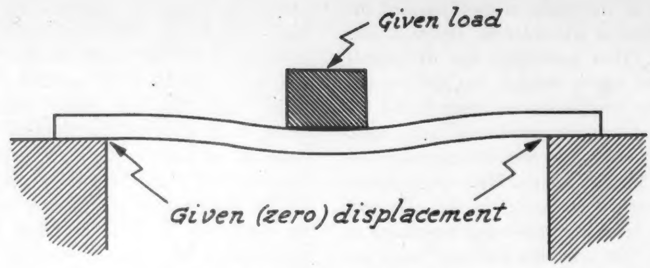


Fig. 7. Boundary of an elastic beam.

Helmholtz' theorems were cast into a new form by Lord Kelvin (7) in 1869. Kelvin introduced a still more important new concept. Consider a closed loop of fluid particles, and at each point project the velocity of the fluid onto the tangent to the loop. The sum of all these projections Kelvin called the "circulation" of the loop (Fig. 5). The circulation is a measure of the average rate of turning of the loop. Kelvin proved then that Helmholtz' theorems are equivalent to a single statement: The circulation of a loop of fluid particles remains the same throughout its motion. That is, however the fluid loop is turned, pulled, and twisted as the spinning motion proceeds, its circulation is unaltered. Kelvin's theorem plainly exhibits qualities i and ii above.

Helmholtz' and Kelvin's theorems refer to a problem that was one hundred years old when they wrote; these theorems are now themselves nearly one hundred years old. A beautiful addition to precisely this same subject—spinning motions of ideal fluids—was made in 1950 by the German meteorologist Hans Ertel (8). Consider a steady spinning motion whose paths are closed circuits perpendicular to a certain surface (Fig. 6). The character of this motion is assumed not to change in time. That being the case, any one particle on one of the circuits takes as long to go around it as does any other particle on the same circuit. Thus, each circuit has a definite time of travel, or *period*. For two hundred years it has been known that each path has a definite *energy*; Kelvin's theorem asserts that each path has a definite, constant *circulation*. Ertel had the insight to perceive that circulation, energy, and period must be related, and for two neighboring circuits he proved that

$$\text{Period} = \frac{\text{Difference of circulations}}{\text{Difference of energies}}$$

While the theorems of Helmholtz and Kelvin provide a geometrical picture, Ertel's theorem gives us the first insight into the time a fluid requires to execute a spinning motion.

Small Elastic Deformations

Next to fluid mechanics, the oldest branch of the mechanics of materials is elasticity, the science of the deformation of bodies under load. The basic equations for slight changes of shape have been established for 125 years. For about seventy-five years we have known two alternative ways of stating these fundamental laws in terms of economy: (i) Among all changes of shape consistent with given displacement on the boundary, that which occurs according to linear elasticity yields the least stored energy. (ii) Among all statically possible interior forces consistent with given forces applied on the boundary, those which occur according to linear elasticity yield the least complementary energy.

In the second theorem, "complementary energy" means stored energy less the work done by the surface loads in producing the surface displacements. Both these statements are what are called "variational principles." In comparing different conceivable states of a

deformed body, they assert that the state actually occurring is such as to give to a certain quantity the least possible value. Variational principles are prized for four reasons: (i) they characterize an entire theory in terms of a single simple concept; (ii) they are equally valid for all methods of description; (iii) they may often be used to prove analytical theorems regarding the subject; (iv) they may often be used to calculate numerical solutions in special cases.

For the linear elasticity theory, the two classical variational formulations are different. One refers to displacements, the other to interior forces. If, as often happens (Fig. 7), on a part of the boundary the displacement is given, while on another part the loads are given, neither principle can be applied. For each principle, one half of the equations of the theory are regarded as known, while the other half are consequences of the principle; in the two principles, the two halves of the basic equations play interchanged roles. This is unfortunate, since a variational principle should express the situation in its entirety.

In 1950 Eric Reissner of Cambridge, Massachusetts, established a new variational principle in which nothing is presumed. On part of the boundary the loads may be given; on other parts, the displacement; on still other parts, a portion of the load and a portion of the displacement. In the comparison of different possible states, all six measures of internal force and all six measures of deformation are varied. In 1914 Ernst Hellinger (*9*) had defined what might be called a new type of stored energy, depending on all 12 of these quantities, and he had proved a variational theorem for it. Reissner rediscovered Hellinger's result and completed it by considering every possible type of boundary condition. He proved that giving this new energy the smallest value consistent with the given loads and displacements on the boundary is equivalent to satisfying the entire set of equations of elasticity theory. Thus, a fully general variational expression, including as special cases both the old ones, has been proved.

Just over a century ago Barré de St. Venant (*10*) created an ingenious method for finding the interior forces and deformations when a bar is twisted. In this method, the total torque twisting the bar may be assigned, but the detailed distribution of load on the ends of the bar is determined by the method and cannot be assigned at will. Thus, the method does not yield a fully general solution of the elastic problem. St. Venant reasoned that this should make no difference. When a bar is twisted in an experiment, it is usually impossible to ascertain the distribution of load. All that is known, usually, is the over-all torque (Fig. 8). Near the end itself, different loadings may produce considerably different effects, but far down the bar no difference is perceptible, provided that the total torque is the same. Thirty years later Jean Boussinesq (*11*) expressed St. Venant's suggestion essentially as follows: The difference between the effects produced by two different but equivalent loads applied in a given part of the body becomes very small at great distances from that part. Two loads are "equivalent" if they would have exactly the same effect on the body if it were rigid. The notion just expressed has been generally accepted and is called "St. Venant's principle."

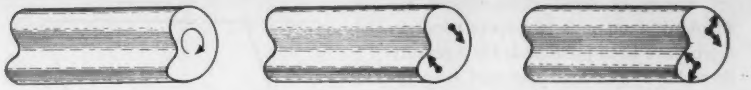


Fig. 8. Equivalent end loads twisting a bar.

In the attitude toward St. Venant's principle we may illustrate a difference between engineering, or applied mechanics, and rational mechanics. St. Venant's principle can be subjected to partial test by experiment. It has been tested and found good. Therefore it is used with confidence by engineers. Every time they design a bridge or ship they apply St. Venant's principle repeatedly, if often unconsciously. In rational mechanics, however, elasticity is a mathematical theory whose basic equations are fixed once and for all. If St. Venant's principle is true, it should be *proved* as a mathematical theorem. Indeed, there have been many unsuccessful attempts to prove it.

If proof of St. Venant's principle were a problem in pure analysis, I should not mention it here. Like other real problems of rational mechanics, it required a preliminary searching of concepts. My statement of it above is vague, and several different statements have been proposed. All these were reviewed in 1945 by the late Richard von Mises (*12*) of Cambridge, Massachusetts, and he showed all to be either trivial or false. Von Mises proposed to consider the case when loads are applied within a small sphere of radius r, which is then allowed to shrink (Fig. 9). At a fixed point within the body, we should try to show that, as r approaches zero, the effects of two equivalent loads in the sphere are of more nearly the same order of magnitude than are the effects of two nonequivalent loads. By examples of a special kind, von Mises showed that this formulation could not be correct, and he proposed a stronger one.

In 1954 Eli Sternberg (*13*) of Chicago put von Mises' views into general mathematical form and thus at last produced a definite enunciation, capable of proof or disproof. Notice that what was involved in the first 99 years of this problem's history was search of the *concepts* preliminary to use of the analytical tools usually associated with mathematics. Sternberg proceeded to construct a strict proof, and he proved St. Venant's principle *false*. However, he was able to show that additional restrictions, similar to those suggested by von Mises and realized in many cases of application, render it true. For example, if the loads are parallel to a fixed direction, and if the two loadings remain equivalent when rotated, St. Venant's principle is true.

Large Elastic Deformations

While the foregoing researches fall within the theory of small elastic deformations, that theory itself is insufficient to describe the behavior of materials such as rubber, which may be stretched severely yet springs back to its former shape. Some seventy or eighty years ago, a mathematically proper theory for large elastic deformations was formulated. However, although this theory is an old one, its status is different from that of the only-a-little-older theory of small deformation. University courses in

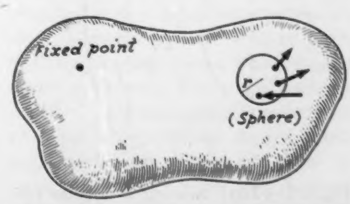


Fig. 9. Von Mises' formulation of St. Venant's principle.

the theory of small deformations are standard; thousands of papers concerning it have been published; for a century there have been textbooks and even reliable treatises upon it. The theory of large deformations, on the other hand, has been known by only a few; few have been the papers concerning it, and from 1900 to 1948 general knowledge of it declined to the point where many specialists in mechanics were partially unaware of its existence. It was not until 1948 that the first book concerning it was published, in Russian.

An exception to the foregoing statements is provided by the work of Antonio Signorini (*14*) in Rome. Of all the persons I shall mention in this article, Signorini is the only one whose position is that of "professor of rational mechanics." From the 1930's until the present time, Signorini and his pupils have sustained classical knowledge and have made important additions. First I mention a beautiful and simple theory of mean values, noticed by Signorini in 1933 and later extended. For any kind of material, whether elastic or not, this theory enables us to estimate the *average* internal forces if we know the loads applied. Hence result very simple bounds for the greatest internal force.

In elasticity itself, the approach of Signorini has been to conjecture the particular manner in which the stored energy depends upon the deformation. Adopting one or another form as a hypothesis, Signorini explores the properties of such a material and checks them against experimental behavior of real materials. Signorini has obtained some success with certain particular theories.

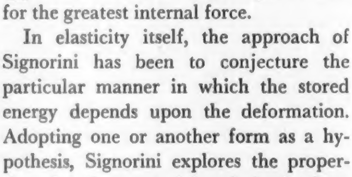


Fig. 10. (Top) twisting a circular rod; (bottom) bending a rectangular block.

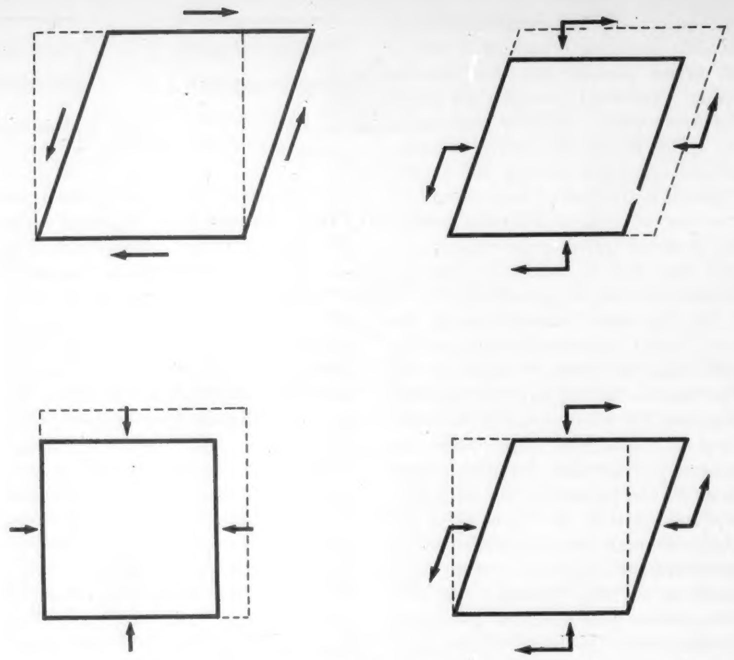


Fig. 11. Compression and shear in a linear theory.

While superficially this attack may resemble that of the many semiempirical engineering studies on large deformations, in fact Signorini's work is different in character and very precise. In my opinion, later researches show this approach to be inadequate, but there are by-products for which no counterpart is yet known in the more general work to be described presently. These by-products are restrictions on the manner in which the various measures of elasticity of a body may depend upon its temperature. Naturally such restrictions arise in part from the laws of thermodynamics, which are included in the general system of mechanics. In particular, restrictions upon the internal energy are shown to be consequences of the form of the stored elastic energy.

A basically new attack upon large elastic deformations was initiated in 1948 by Ronald Rivlin (*15*), then in London. For bodies whose volume cannot change, no matter how they are deformed, he sought exact solutions for simple but important problems. His fundamental departure was to leave the form of the stored energy function *entirely unrestricted*. The equations of the theory are so complicated that an approach of such generality would seem hopeless. In fact, only the idea had been wanting; the calculations turned out to be easy. Rivlin found the fully general solutions for twisting a circular rod (Fig. 10, top) for bending a rectangular block (Fig. 10, bottom) and for several other cases. These solutions were compared with experimental measurements on rubber, and in this way the form of the stored energy function for rubber was determined. The measurements showed that none of the forms which had been guessed at various times by various persons were physically correct. In particular, forms suggested by the common argument that the effects of certain "small" quantities may be neglected were shown to be inadequate. By substituting the experimental form in other particular solutions, Rivlin was able to predict the behavior of rubber in cases when it was stretched to twice and even three times its initial length, with an accuracy of a few percent. This is a remarkable achievement. Here I must add that "small" in the old theory of small deformations means "almost invisibly small": a change in length of 1 percent is usually too great for adequate description by the theory in books on elasticity. Second, it had been known for a century that rubber does not follow the predictions of the theory of small elastic deformations, and many researches of a

physical or chemical nature had been devoted to attempts to get a proper theory for rubber from hypotheses regarding its molecular structure. The new researches in elasticity show that the mechanical behavior of rubber is fully and precisely predicted by purely mechanical principles, *providing they are not degraded by so-called "approximations."* In respect to application to physical phenomena, this was a triumph of the principles of mechanics and of generality. Out of Rivlin's work has grown a new branch of engineering which might be called "applied mechanics for rubber."

Other Nonlinear Theories

In 1945 a new pathway was opened by Marcus Reiner (*16*), in Haifa. Originally he dealt with fluids rather than solids, but it was soon realized that a new general method in the mechanics of nonlinear materials was available. Before going further I must explain the terms *linear* and *nonlinear*. In a linear theory, two causes applied at once produce the same effects as if first one, then the other, were applied singly. For example, if we first shear, then compress, a block, in a linear theory the result is the same as if we reverse the order or compress and shear simultaneously (Fig. 11). In a nonlinear theory, this need not be so. In fact, in a nonlinear theory it is generally necessary to apply compressive force in order for a shear without compression to be possible (Fig. 12). The compressive force appears to do nothing whatever, but if it is not applied, the body will expand. A more familiar effect of nonlinearity is seen in the gyroscope, which usually swings over in a direction quite different from that in which it is pushed. Mechanics as a whole is nonlinear; the special parts of mechanics which are linear may seem nearer to common sense, but all this indicates is that good sense in mechanics is uncommon. We should not be resentful if materials show character instead of docile obedience.

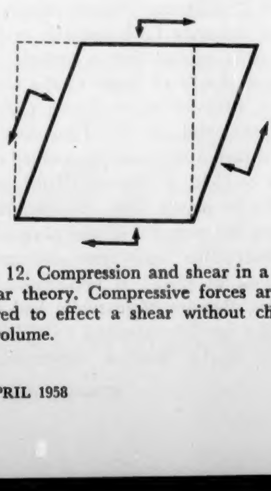


Fig. 12. Compression and shear in a nonlinear theory. Compressive forces are required to effect a shear without change of volume.

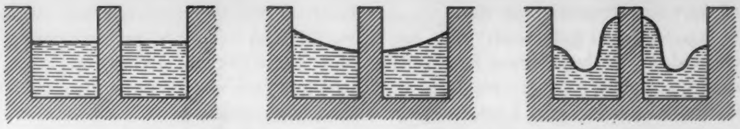


Fig. 13. (Left) rest; (center) rotation, linear fluid; (right) rotation, nonlinear fluid.

Although mechanics is essentially nonlinear, it is little exaggeration to say that for 150 years only linear mechanics and its mathematics were studied. It became standard practice, after deriving the equations for a phenomenon, to replace them at once by a linear so-called "approximation." It would be wrong to regard this mangling as being in the original tradition of mechanics. In fact, only after a century of development was it generally recognized that linearity is synonymous with easiness. The linearizing set in about 1780 but did not gain undisputed mastery until toward the end of the last century, under the influence of Lord Rayleigh. Indeed, there are many physical situations in which a linear theory is adequate. This does not alter the fact that in many other situations linearization is unjustified; and both the mathematics and the mechanical principles associated with nonlinear phenomena are much more interesting.

While a century of linearization may have largely exhausted its capacities for explaining physical phenomena and have allowed its mathematics to be explored almost to the full, it has fostered a certain rigidity of approach which might be called "linear thinking." This has made a return to nonlinear problems more difficult in fact than perhaps a few years hence it may appear to have been. In particular, it has engendered an emotion somewhere between apathy and fear in the reception that nonlinear studies are accorded by the great majority of researchers, who today remain absorbed in conventional linear problems.

The work of Reiner in 1945 and similar work by William Prager (*17*) in 1945 and by Rivlin (*18*) in 1948 put into our hands a new tool for exploration of nonlinear phenomena in materials. Basically, their major result is a revival of an old but little-known theorem in algebra, having broad usefulness in mechanics. It is applicable to any material, whether fluid or solid, so long as the internal forces arise solely in response to a single measure of deformation. The example above concerning simple shear is an entirely typical consequence of this new approach. Another application, in essence the same, is this: When an elastic rod is twisted a little, it will elongate proportionally to the square of the angle of twist. Another application of the same principle is this: When a fluid is rotated about a fixed cylinder, it will climb up the cylinder, the force required to prevent such a rise being proportional to the square of the rate of rotation (Fig. 13). The former effect had long been known experimentally. While the latter had been observed specifically only at about the same time, it was quickly recognized as familiar. In the paint industry, for example, rotary stirrers were found to have little effect because the paint agglomerated upon them. Various physical and chemical explanations were given for this effect, but the theory of nonlinear fluids accounts for it easily and naturally on purely mechanical grounds. Rivlin calculated exact solutions for the configurations occurring in viscometers, and when viscometers which could measure the new effects had been constructed, experimental agreement was found.

It would be misleading to emphasize unduly the success of the nonlinear theory in predicting these phenomena. To form a particular theory such as to agree with any particular measurement is not nearly so difficult as it might seem. Indeed, *special* theories of nonlinear elasticity and nonlinear fluids had been constructed in some number during the 1930's and 1940's, and it is only the rule that such researches always include experimental data fully confirming the theory. What is new in the work just described is its *independence* on experiment. The new approach gives us a unified view, a grasp upon a whole class of nonlinear theories. The major result established, in respect to experimental application, is that virtually *any* reasonable nonlinear theory will predict these effects, so that their experimental occurrence, while indeed showing nonlinearity

in real materials, does not confirm any of the numerous special theories.

You will notice that my tone has changed. While the advances I first discussed concerned specific problems in established theories, now I am surveying the discovery of *new theories* of mechanical behavior. This—the most absorbing aspect of modern mechanics—dominates the field today.

While I have praised generality, we must have a care of its dangers. It is easy to think of a material which, instead of using up work when it is deformed, gives it out. Such a material, indeed, we can think of, but, at least so far, it is not interesting in mechanics. This and more subtle misbehaviors we wish to exclude in the theories we create. In 1948 I showed (*19*) that, without surrendering the inclusiveness of the work of Reiner and Rivlin, we can classify nonlinear materials by dimensional analysis. The results enable us to discard at one stroke many materials that might otherwise seem reasonable. In regard to elasticity, in 1952 I proposed a more specific requirement (*20*): When a body has been deformed, additional deformation requires additional stored energy. This is not so trivial as it sounds, since what is meant by "additional deformation" is not obvious. This principle turned out to imply restrictions on the stored energy function. In 1942, M. Baker and Jerald Ericksen (*21*) of Washington replaced this idea by a more general one applicable to fluids as well as to solids. In 1955 I pointed out (*22*) that requirements of this type are closely connected with wave propagation: A body so unreasonable as to refuse passage to waves may also do other and more obviously objectionable things. At the same time, Ericksen and Richard Toupin (*23*) of Washington established a connection between these requirements and those of uniqueness. According to one of their results, a deformed body properly receptive toward waves is also unwilling to deform further in more than one way in response to given small additional displacements upon its boundaries. This class of problems, whose objective is to distinguish liberty from license, is still under study.

Here I pause to answer a heartfelt question of many a reader: Why don't we measure all these things? First, measurement in mechanics is not so easy as it might seem. Despite objections from philosophers of science, mechanics has always been expressed largely in terms of quantities that are themselves usually not measurable. Had there been operationalists alive in 1750, the design of a bridge in 1958 would proceed more awkwardly than it does in any engineering office today. Second, we have had more than a century of experimentation, often on a large scale and at great cost, regarding the mechanical behavior of materials. Had experiment settled these matters, I should not be writing about them here. Experimental mechanics is a recognized field which needs no defense; it has its own problems, its own methods, its own results, its successes, and its failures. It may, but need not, cooperate with applied mechanics and with rational mechanics; these, in their turn, may, but need not, cooperate with it. Without *experience* there would be no rational mechanics; but I should mislead you if I claimed that experiment, either now or two hundred years ago, has greatly influenced those who study rational mechanics. In this connection experiment, like alcohol, is a stimulant to be taken with caution: to consult the oracle of a fine vintage at decent intervals exhilarates, but excess of the common stock brings stupor.

Students of rational mechanics spend much effort thinking *how materials might possibly behave*. These thoughts have not been unproductive of information on how some materials do behave. Real materials are not naive; neither are they irrational.

In their behavior, materials always act in just the same way, no matter who happens to be looking. The response of a material is independent of the observer. Now this statement becomes less trivial than it might seem when we make two further observations: first, the laws of classical mechanics themselves change most noticeably when the same body is regarded by different observers; second, to express the response of a body in mathematical language we always employ the reference frame of *some* observer. The problem, then, is to find how to limit our ideal materials to those whose response is properly invariant with respect to change of observer.

For the old, linear theories, this problem is trivial and is solved automatically by using well-known principles of tensor analysis. For the nonlinear theories I have just discussed, the problem is relatively easy. But when the interior forces depend on more than one measure of deformation, or when the basic laws connect time rates, the problem becomes relatively difficult. For a very special case of time rates, the problem was set and solved by Augustin Cauchy (*24*) a century ago; in rather more general but still limited circumstances, by Stanislas Zaremba (*25*) in 1903. The nature of the general problem and a correct solution of it was first indicated in 1950 by J. G. Oldroyd (*26*), then working in Maidenhead. A more satisfying treatment was given in 1955 by Walter Noll (*27*), then in Bloomington. Noll's formulation is in terms of a principle he calls "the isotropy of space," by which the basic equations of any proposed ideal material can be tested for invariance. Similar methods, somewhat different in detail and scope, were introduced in two papers written by Rivlin (*28*) jointly with Ericksen and with Barbara Cotter of Providence; the method of Zaremba was rediscovered and extended by Tracy Y. Thomas (*29*) of Bloomington.

By use of his principle, Noll was able to construct the first adequate theory of the *continuity of the solid and fluid states* (*27*). In this unified theory appear materials which show the responses both of solids and of fluids, the nonlinear theories of pure elasticity and pure fluidity being included as extreme possibilities. The idea of such materials had been put forward a century earlier by James Clerk Maxwell (*30*) and had been explored with partial success by Zaremba (*25*), but Noll's work is the first to combine exactness and completeness. Noll obtained exact solutions for certain special deformations and showed that his theory implies breakdown of smooth motion at high speeds. A possible theory of continuous transition from ordinary behavior to ultimate failure or breakage has thus been initiated.

In 1953 I proposed (*31*) a more modest but at the same time more definite theory of elastic behavior. My idea was, instead of relating the interior forces to the deformation, to connect the rate of change of the interior forces with the rate of change of shape. The resulting theory, called "hypoelasticity," agrees with the old linear theory for small changes of shape but for large changes is entirely different. This new theory has turned out to be fairly general; in 1955 Noll (*27*) proved that it includes the classical theory of large elastic strain, and in 1955–56 Albert Green (*32*) of Newcastle and T. Y. Thomas (*33*) proved that, apart from an assumed condition of yield, it contains all the usual theories of plastic flow, provided those theories are corrected in several respects. The reservation "apart from an assumed condition of yield" is important. For decades, theories of plasticity had employed a specially assumed condition to express plastic flow—a semiempirical

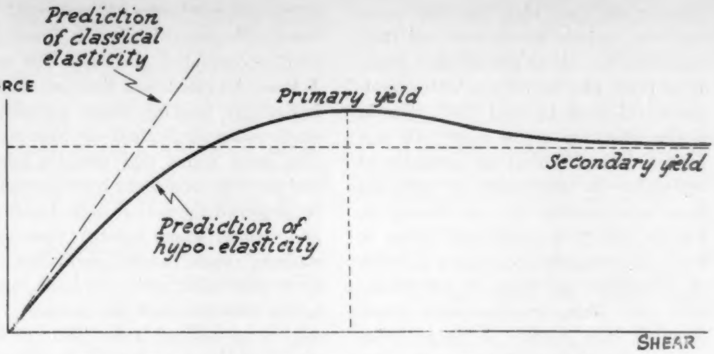


Fig. 14. Primary and secondary yield predicted by hypoelasticity.

compromise between experiment and theory unrelated to other parts of mechanics. I had long felt that this was unfortunate; that in fact yield is a phenomenon which should be *predicted*, not assumed, by a proper theory; that a true mechanical theory should include plastic flow not as a primary condition but as the *result* of previous circumstances leading up to elastic failure. In 1955 I showed (*34*) that, in certain cases, hypoelasticity furnishes a smooth and simple theory of just the type desired. For certain hypoelastic bodies in shear, the force required to effect the shear has been proved to follow a curve such as that shown in Fig. 14.

Statistical Mechanics

To conclude the list of advances, I wish to return from exploration of new theories and consider progress in an old, established theory: statistical mechanics. In statistical mechanics, apparently continuous matter is represented as a very numerous assembly of little points called "molecules," which are in rapid and largely independent motion. The object is to relate quantities of experience, such as force and velocity, to *averages* over the molecular assembly. Averages of this kind are called "phase averages." The conditions defining a particular motion of the molecules are not known. Rather, a whole class of such motions is laid down as being possible, and each motion within this class is assigned a *probability* of occurrence.

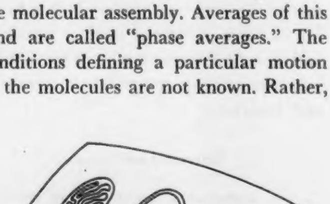


Fig. 15. Scheme to suggest ergodic motion.

In introducing such averages about eighty years ago, Maxwell (*35*) remarked on the difficulty of convincing oneself that such purely mathematical quantities are appropriate for comparison with physical measurements. In the particular kind of phase average he recommended, every motion admitted has the same energy, and all such motions are equally probable. He suggested that a complicated mechanical system, if left to itself, would eventually assume nearly every configuration consistent with its assigned energy. If we think of the motion as a curve, this curve would be so tortuous as to occupy, at one time or another, nearly every point on the surface consisting of its possible configurations (Fig. 15). For such a motion, the average behavior of a given system over a long time would equal the average over all possible motions at any one instant:

Time average = phase average

Motion of the type Maxwell suggested was quickly shown to be impossible, yet the possibility remained that his conclusion could be true.

The "ergodic problem," as the problem of proving this conjecture came to be called, drew the attention of many mathematicians, and in the 1930's it was solved. The conclusion, as far as mechanics is concerned, was negative. In order that the time average be exactly equal to the phase average, for *every quantity* and for *all but utterly improbable ways* of setting the system in motion, a condition emerged which was inappropriate to the mechanical problem and not reasonably to be expected. While an extensive and interesting part of pure mathematics grew from this idea, no progress in mechanics resulted.

In any case, Maxwell's type of average (which came to be called "microcanonical"), for reasons of mathematical difficulty usually could not be evaluated. Even before Maxwell's work, Ludwig Boltzmann (*36*) had introduced another kind of phase average, later called "canonical." No mechanical principle or idea lies behind this kind of average. Rather, its reason for existence is *mathematical* simplicity: With canonical averages, a patient person can get answers, and virtually all explicit statistical mechanics as applied to chemistry and physics has rested upon canonical averages from that day to this. Nowadays many scientists are willing to compare canonical averages with measurements and, finding them valid, to accept the theory based upon them as being justified directly by experiment. This was not Boltzmann's idea at all. Boltzmann attempted to prove that, as the number of molecules in the system becomes very large,

Microcanonical average $\rightarrow$ canonical average

In several attempts, Boltzmann claimed to give analytical proofs (*37*) of this conclusion, which is called "Boltzmann's law." One of these proofs is often reproduced in courses today, but, like the others, it is unsound. Such was the insecurity of the conclusion that, in his book on statistical mechanics (*5*), Gibbs did not even mention it. In the 1920's, Darwin and Fowler achieved a satisfactory but rather difficult proof.

This was the situation when the Russian mathematician A. Y. Khinchin (*38*) took up the subject in 1943. First, he gave a new, somewhat simpler, proof of Boltzmann's law along lines nearer to the ideas of the classical theory of probability. If this were all, I should not be mentioning it here, but this was an essential preliminary to his solving a much deeper problem—the true ergodic problem of statistical mechanics.

In looking back on the ergodic problem, Khinchin realized that the mathematicians of the 1930's had asked too much. First, they had required that the time average be exactly equal to the phase average, while for mechanics it would be enough that the error be small. Second, they had required that equality hold with only utterly improbable exceptions, while it would be enough that the exceptional cases be rather improbable. Third, they had required that the equality hold for every sort of quantity that might be averaged, while in fact only a limited class of quantities are ap-

propriate for averaging in a mechanical system. The third idea gave the real clue. A quantity that has nearly the same value for all possible configurations will certainly have a nearly constant average in time for a given system. It is almost trivial to remark that, for such a quantity, the phase average and the time average are almost the same. But what Khinchin was apparently the first to realize is that Boltzmann's law itself implies that the quantities which are to be averaged are indeed nearly constant over most possible configurations! He then went back over his proof of Boltzmann's law and sharpened it sufficiently to estimate the average error. With this estimate, he was then able to establish the ergodic principle along the lines just indicated. In the sequence

Time average →
microcanonical average →
canonical average

proof of the second stage was shown very elegantly to yield proof of the first stage as a by-product. Khinchin's result, in full, may be put as follows: The cases when the time average differs very much from the canonical average become, as the number of molecules in the system is taken larger and larger, of arbitrarily small probability. In this statement we perceive another difference from ergodic theory, which is just as applicable to two marbles in a box as it is to a solid body with trillions of molecules; Khinchin's result, like Boltzmann's law, is a theorem appropriate only to complicated and numerous systems.

Khinchin's brilliant success has been little appreciated. On the one hand, most physicists have lost interest in the problem. On the other hand, mathematicians trained in ergodic theory find the case too special to be interesting. In my opinion, Khinchin's analysis is a masterpiece in rational mechanics, fully justifying the original view of Boltzmann. It shows that every time a chemist calculates a canonical free energy, he is calculating in fact the average free energy in a system of fixed total energy left to itself for a long time.

While the foregoing analysis refers to systems in equilibrium, the statistical mechanics of deforming media furnishes even more interesting problems. Until recently the statistical mechanics of fluids, for example, was regarded as different and presumably more accurate than theories representing fluids as continuous. That this is not the case was shown in 1950 by Jack Irving and John Kirkwood (*39*) of Pasadena. They contributed the basic idea, but their proof was not entirely satisfactory and their approach was not as general as it might have been, and in 1955 a better treatment was given by Noll (*40*), then in Berlin. His form of the result will now be summarized. Given any assembly of molecules, be they alike or different from one another, few or numerous, free or subject to any outside forces or forces of interaction, consider a selection of probability according to any admissible rule. Then, by appropriate phase averages, it is possible to define mean velocity, mean internal force, mean internal energy, and mean flow of energy in such a way that *they satisfy exactly the field equations for continuous materials*. Thus, statistical mechanics and field mechanics are united. By considering a fluid or solid as an assembly of molecules, it is impossible to derive anything that is in contradiction to the view of matter as continuous. Conversely, there is nothing in the continuous view of matter that is not also in accord with a molecular picture. With this beautiful unification of the two apparently opposing views of matter, I close the list of examples.

Apology

What I have presented shows the power and versatility of modern rational mechanics. You may expect me to say now that these achievements are only a small part of the great things that have been done, but that would be misleading. Indeed, in a longer article I would describe the work of Eberhard Hopf on turbulence, of T. Y. Thomas on the paths of dynamical systems and on the stability of shock waves, of Otto Ringleb, Walter Tollmien, and Kurt Friedrichs on transsonic gas flows, of Paul Neményi and Robert Prim on rotational gas flows, of Bruce Hicks, Prim, and Ericksen on the streamlines of gas flows, of Lavrentiev, David Gilbarg, and James Serrin on water flows past cavities, of Einstein, S. N. Bose, and Vaclav Hlavatý on the new unified field theories, and of Toupin on elastic dielectrics; I would describe some further studies of vorticity, and some other things. However, the list would not be very long.

Indeed, I must conclude with an apology for rational mechanics. It is not likely to become a popular field. No prizes are awarded for rational mechanics, and it would make a poor showing in a poll of the public or of scientists in general. The monetary cost of a century of rational mechanics will not equal the hundredth part of what is spent this year on computing machines. The work I have described was done slowly, by individuals working alone or with a single other individual of like tastes. The great teams that produce bombs and vaccines would not have multiplied or deepened the output here. In an age and country where numbers, cost, and statistics count, rational mechanics will never gain much notice. In itself, notice is not what we need, but nowadays he who is not noticed is not likely to survive. In rational mechanics the financial need is on so small a scale that often it goes entirely unrecognized, in favor of more costly and more glittering projects. Whether in universities or outside them, several of the persons whom I have named lack a proper library, secretarial help, and even adequate stationery, not to mention a reasonable allowance of time for work free of teaching or other community responsibility. There is no society for rational mechanics, nor are its individualist students likely ever to be numerous enough to afford one or cooperative enough to establish one. For at least twenty-five years no one has been elected to membership in the National Academy of Sciences for achievement in rational mechanics.

As far as costs and numbers go there has been little change. It would be quite incorrect to assume either that the "classical" mechanics we learn today as the first step in physics and engineering was produced by a cooperative effort of organized science or that, in those old-fashioned days, no large projects existed. Indeed, two hundred years ago much money was spent on science: on the calculation of great numerical tables, on extensive experiments for the betterment of mankind, on the design of warships, on the establishment of boards and committees to organize science. But these efforts did not produce the "classical" mechanics; this was the work of a handful of men, scattered over a continent and a century—men who were willful, uncompromising, quarrelsome, arrogant, and creative.

References and Notes

1. For mathematical presentation of much of the work described in this survey, see the following: C. Truesdell, "Mechanical Foundations of Elasticity and Fluid Dynamics," *J. Rational Mech. and Analysis* 1, 125 (1952); 2, 593 (1953); "Kinematics of Vorticity," *Indiana Univ. Sci. Ser. No. 19* (1954). Revised and greatly amplified versions of these works will be included in the following articles in the *Handbuch der Physik* (in press): C. Truesdell, J. L. Ericksen, R. Toupin, "The Classical Field Theories," and W. Noll, J. L. Ericksen, C. Truesdell, "The

Nonlinear Field Theories of Mechanics." A nonmathematical description of some parts is given in C. Truesdell, "Program of Physical Research in Classical Mechanics," *Z. angew. Math. u. Physik* 3, 79 (1952). For the historical side, an enlightening description of the struggles of the pioneers is given by R. Dugas [*La Mécanique au XVII^e Siècle* (Griffon, Neuchâtel, Switzerland, 1954)]. Much of the history of the creation of the classical theories of elasticity and fluid dynamics in the 18th century is written in my introductions to *L. Euleri Opera Omnia* (Zürich and Lausanne, Switzerland) ser. II, vols. 12 (1954) and 13 (1955), and vol. 11, in press.

2. In connection with this paragraph, see C. Truesdell, "Experience, Theory, and Experiment," *Proc. Conf. on Hydraulics (1955)* (Iowa City, Iowa, 1956).
3. I. Newton, *Philosophiae naturalis principia mathematica* (London, 1687; ed. 3, London, 1726). There are several reprints; a not altogether reliable English translation was published at Berkeley, California, in 1934. A new critical edition and translation by Alexander Koyré and I. Bernard Cohen is in preparation.
4. D. Hilbert, "Mathematische Probleme," *Nachr. Ges. Wiss. Göttingen* 1900, 253 (1900). An English translation of an amplified version is given in the *Bull. Am. Math. Soc.* (2) 8, 437 (1902).
5. J. W. Gibbs, *Elementary Principles in Statistical Mechanics* (New York and London, 1902); reprinted in Gibbs' *Collected Papers*, vol. 2.
6. H. von Helmholtz, "Ueber Integrale der hydrodynamischen Gleichungen, welche den Wirbelbewegungen entsprechen," *J. reine u. angew. Math.* 55, 25 (1858); reprinted in *Wissenschaftliche Abhandlungen*, vol. 1, pp. 101–134. An English translation appeared in *Phil. Mag.* 33, 485 (1867).
7. W. Thomson (Lord Kelvin), "On vortex motion," *Trans. Roy. Soc. Edinburgh* 25, 217 (1869); reprinted in *Collected Papers*, vol. 4, pp. 13–66.
8. H. Ertel, *Misc. Acad. Berolinensia Ges. Abhandl. Feier deut. Akad. Wiss. Berlin* 1, 62 (1950).
9. E. Hellinger, *Enzykl. math. Wiss.* 4^4, 602 (1914).
10. B. de St. Venant, "Mémoire sur la torsion des prismes," *Mémoires des savants étrangers acad. sci. Paris* (1855).
11. J. Boussinesq, *Application des potentiels* (Gauthier-Villars, Paris, 1885).
12. R. von Mises, *Bull. Am. Math. Soc.* 51, 555 (1945).
13. E. Sternberg, *Quart. Appl. Mathematics* 11, 393 (1953).
14. For references to Signorini's numerous papers on elasticity, see C. Truesdell, "Mechanical Foundations of Elasticity and Fluid Dynamics," *J. Rational Mech. and Analysis* 1, 125 (1952); 2, 593 (1953). The theory described in the text is given in A. Signorini, "Sopra alcune questioni di statica dei sistemi continui," *Ann. scuola normale superiore Pisa* 2, 231 (1933), in "Sulle proprietà di media comuni a tutti i sistemi continui," *Atti reale accad. Italia. Rend.* 2, 728 (1941), and in later papers. A survey of this work will be included in C. Truesdell, J. Ericksen, R. Toupin, "The Classical Field Theories," *Handbuch der Physik*, in press.
15. For references to the numerous publications of Rivlin, see C. Truesdell, "Mechanical Foundations of Elasticity and Fluid Dynamics," *J. Rational Mech. and Analysis* 1, 125 (1952); 2, 593 (1953). I mention in particular R. S. Rivlin, "Large Elastic Deformations of Isotropic Materials," parts IV and V, *Phil. Trans. Roy. Soc. London* A241, 379 (1948), and *Proc. Roy. Soc. (London)* A195, 463 (1949).
16. M. Reiner, *Am. J. Mathematics* 67, 350 (1945).
17. W. Prager, *J. Appl. Phys.* 16, 837 (1945).
18. R. S. Rivlin, *Proc. Roy. Soc. (London)* A193, 260 (1948); *Proc. Cambridge Phil. Soc.* 45, 88 (1949).
19. C. Truesdell, "A New Definition of a Fluid," *U.S. Naval Ordnance Laboratory Memorandum No. 9487* (unclassified) (1948); *J. math. pures appl.* 29, 215 (1950); 30, 111 (1951).
20. Included in C. Truesdell, "Mechanical Foundations of Elasticity and Fluid Dynamics," *J. Rational Mech. and Analysis* 1, 125 (1952); 2, 593 (1953).
21. M. Baker and J. L. Ericksen, *J. Wash. Acad. Sci.* 44, 33 (1954).
22. C. Truesdell, *Z. angew. Math. u. Mech.* 36, 97 (1956).
23. J. L. Ericksen and R. A. Toupin, *Can. J. Mathematics* 8, 432 (1956).
24. A.-L. Cauchy, "Sur l'équilibre et le mouvement intérieur des corps considérés comme des masses continues," *Exercises de mathématique* 4 (1829); reprinted in *Oeuvres complètes*, vol. 9, pp. 342–369.
25. S. Zaremba, "Sur une forme perfectionnée de la théorie de la relaxation," *Bull. intern. acad. sci. Cracovie* 1903, 594 (1903); also, "Sur une conception nouvelle des forces intérieures dans un fluide en mouvement," *Mém. sci. math. Paris* No. 82 (1937).
26. J. G. Oldroyd, *Proc. Roy. Soc. (London)* A200, 523 (1950).
27. W. Noll, *J. Rational Mech. and Analysis* 4, 3 (1955).
28. R. S. Rivlin and J. L. Ericksen, *ibid.* 4, 323 (1955); B. Cotter and R. S. Rivlin, *Quart. Appl. Mathematics* 13, 177 (1955).
29. T. Y. Thomas, *Proc. Natl. Acad. Sci. U.S.* 41, 762 (1955).
30. J. C. Maxwell, "On the dynamical theory of gases," *Phil. Trans. Roy. Soc. (London)* A157, 49 (1867); reprinted in *Phil. Mag.* 35, 129, 185 (1868) and *Scientific Papers* vol. 2, pp. 26–78.
31. Included in C. Truesdell, "Mechanical Foundations of Elasticity and Fluid Dynamics" [*J. Rational Mech. and Analysis* 1, 125 (1952); 2, 593 (1953)], and given in greater detail in *J. Rational Mech. and Analysis* 4, 83, 1019 (1955), and in *Communs. Pure Appl. Mathematics* 8, 123 (1955).
32. A. E. Green, *Proc. Roy. Soc. (London)* A234, 46 (1956); *J. Rational Mech. and Analysis* 5, 725 (1956).
33. T. Y. Thomas, *Proc. Natl. Acad. Sci. U.S.* 41, 720, 908 (1955).
34. C. Truesdell, *J. Appl. Phys.* 27, 441 (1956).
35. J. C. Maxwell, "On Boltzmann's theorem on the average distribution of energy in a system of material points," *Trans. Cambridge Phil. Soc.* 12, 547 (1879); reprinted in *Scientific Papers* vol. 2, p. 713.
36. L. Boltzmann, "Studien über das Gleichgewicht der lebendigen Kraft zwischen bewegten materiellen Punkten," *Sitzber. kgl. kaiserlichen Akad. Wien* 58^2, 517 (1868); reprinted in *Wissenschaftliche Abhandlungen*, vol. 1.
37. ———, "Beziehung zwischen dem zweiten Hauptsatz der Wärmetheorie und der Wahrscheinlichkeitsrechnung resp. den Sätzen über das Wärmegleichgewicht (Complexionen-Theorie)," *ibid.* 76^2, 373 (1877); reprinted in *Wissenschaftliche Abhandlungen*, vol. 2.
38. A. Y. Khinchin, *Mathematical Foundations of Statistical Mechanics* (Dover, New York, 1949); the Russian original appeared in 1943.
39. J. Irving and J. Kirkwood, *J. Chem. Phys.* 18, 817 (1950).
40. W. Noll, *J. Rational Mech. and Analysis* 4, 627 (1955).

Economics of Nuclear Power

An analysis of when the falling costs of nuclear power will meet the rising costs of conventional power.

John E. Ullmann

It is generally believed that the costs of nuclear power will decrease, and hence it is necessary to attempt a prediction of the time when nuclear power will begin to compete economically with power from conventional steam plants. This is of interest not only to utilities engaged in long-term planning of facilities but also to power users and to equipment manufacturers, who have to assess the competitive pressures exerted by atomic power developments upon their established lines of products. The specific variables of interest are capacity costs and bus-bar costs. Capacity costs are given in dollars per kilowatt of installed generating capacity. Bus-bar costs are the costs of power at the generating station—that is, the costs exclusive of transmission and distribution costs; they are usually given in mills (0.1 cent) per kilowatt hour.

There have been many predictions about the costs of nuclear power. The reasoning behind the growth rate they propose is not, however, generally set forth. The predictions of costs, and hence of break-even points—that is, the time when nuclear and conventional power will cost the same—usually assume that the present conventional power plant capacity and bus-bar costs will remain stable within rather narrow limits. It follows from this view that the price reductions of the future will have to

Mr. Ullmann is on the staff of Columbia University, in the department of industrial and management engineering.

come mainly from the nuclear side and that there will be no corresponding upward movement of conventional costs which would serve to improve the relative economics of nuclear power. This is implied, for example, in the cost charts by Davis and Roddis (*1*) and is specifically listed as an assumption in the McKinney panel report (*2*).

The present analysis is based on two premises. First, it is proposed to review the history of cost reduction in conventional steam plants since 1910 and to apply these rates of cost reduction to nuclear power. In a second step, it is shown that the cost structure of conventional power is likely to prove unstable in the future and that the instability will lead to a considerable rise in costs. The trends from these two analyses are then combined to produce a forecast of break-even points, beyond which nuclear power may be expected to have an increasing economic advantage.

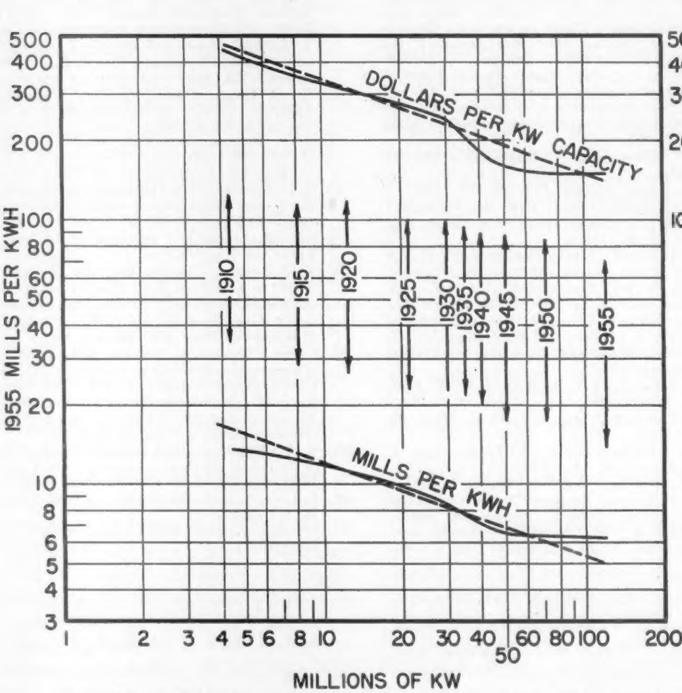


Fig. 1. Cost reductions in conventional steam power, 1910–1955 (*6, 8, 13*).

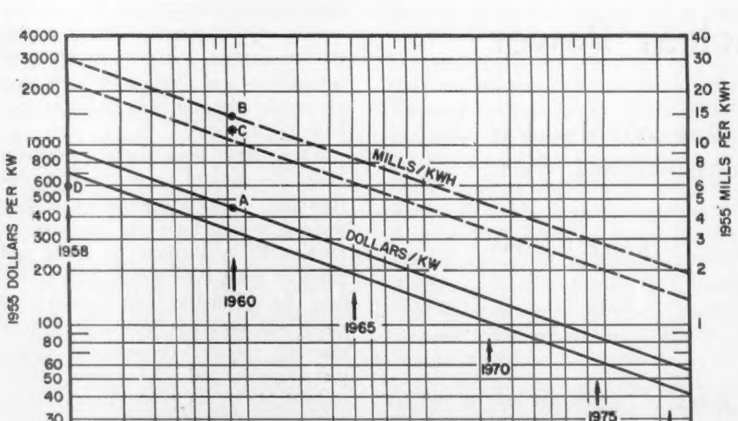


Fig. 2. Anticipated cost reductions in nuclear power, 1958–1980.

Cost Reductions in Conventional Power Plants

The history of the electric power industry in the United States is one of virtually continuous decline in both the investment cost of power plants per unit of capacity and the bus-bar costs of electricity, in the face of increases in the prices of coal and equipment. This trend is shown in Fig. 1, which gives these costs in relation to installed capacity in kilowatts, together with corresponding years. It is thus seen that there is a continuous trend, going back to 1910—some forty-seven years—during which these general reductions have been maintained, even though a recent leveling off is discernible.

It was found that the trend lines fitted to these curves are of almost exactly equal slope (-0.35) and, moreover, that the relationships as a whole bear a resemblance to a "learning curve" (*3*), with "learning" applied to total installed kilowatts rather than to some number of units. With the relationship observed, each successive doubling of capacity has resulted in a 12-percent reduction in cost. The slopes of the curves in Fig. 1, and hence this "learning" rate, are applied to projected costs of nuclear power.

This is considered legitimate because the technologies of the two fields are quite similar, with much equipment—mechanical and, especially, electrical—the same for nuclear as for conventional plants. The equipment is made by essentially the same supplier industry, and the improvements projected for nuclear plants are of the same kind as those with which conventional plants have traditionally neutralized a rising cost level and have actually realized the economies shown in Fig. 1.

For instance, at the Indian Point plant of Consolidated Edison Company of New York, it is proposed to use working pressures of 370 to 420 pounds per square inch (*4*) at a time (1960) when 6000 pounds per square inch or more are envisaged for conventional plants. There is thus quite a margin for refinement in design: working pressures may be increased in nuclear plants, with commensurate economies, just as in conventional plants.

This also implies that problems of safety and waste disposal will be solved. Waste disposal is difficult, though perhaps solutions may be found even before fusion power is developed. The development of fusion power would, of course, reduce the problem greatly. In the absence of adequate operating experience,

safety has also dictated very severe standards in the construction of the first plants. Davis and Roddis (*1*) expect this to constitute a major area for potential savings.

In another design area, Fairman (*4*) has noted the substitution of stainless steel for zirconium fuel containers in the reactor core, thus effecting a saving of some 90 percent, even when the forthcoming lower price of zirconium is taken into consideration. This change was predicted a year ago in the report on "Project Size-up" (*5*). Such important changes demonstrate the maneuverability of present nuclear power technology. In future conventional plants, on the other hand, there are likely to be grave design problems in the simultaneous existence of working temperatures approaching those of today's gas turbines and extremely high pressures (4000 to 6000 pounds per square inch compared with about 90 pounds per square inch in a gas turbine). This equipment must further be suitable for prolonged trouble-free operation.

Initial reports on the Shippingport plant indicate that it uses about 25 to 30 percent more operators per shift than a comparable conventional power plant. In a conventional plant, moreover, much of the labor is employed in handling fuel, whereas, in a nuclear plant, much less labor is required for this purpose. Manpower, too, therefore appears to be a likely area for potential savings. Again, Estcourt (*6*) has pointed out that conventional plants cannot expect to reduce their staffs much more. On the basis of these considerations, it may be said that sufficient leeway exists in present nuclear-plant design to warrant the prediction that there will be decreases in present cost estimates similar to the decreases in cost that have occurred in the production of power by conventional means.

Projection of Nuclear Power Costs

In order to project the cost reductions for nuclear power at the rates of cost reductions experienced in conventional plants, it is necessary first to determine the present levels of nuclear power costs. These are then used as the starting points from which progress in cost reduction can be estimated. The reduction rate also depends on the rate of introduction of nuclear plants, just as the decline in cost of conventional power was related to installed capacity. In order to translate the horizontal, or capacity, scale into years, a rate of introduction of nuclear power must therefore be assumed. Here, the rate suggested by Davis and Roddis (*1*) has been used. As these authors point out, their estimate of 67 percent new nuclear capacity relative to total annual new capacity by 1980 is about the same as other estimates, which they cite. However, they are more optimistic than others in estimating the contribution which this will make to total capacity and generation.

Table 1. Estimated capacities and costs for nuclear plants expected to be operating by 1960.

Name	Capacity (kw) (thousands)	Cost estimate (millions of dollars)	Dollars per kilowatt
Duquesne Power & Light Co., Shippingport, Pa.	100	70	700
Power Reactor Development Co. Inc., Monroe, Mich.	100	48	480
Yankee Atomic Electric Co., Rowe, Mass.	134	57	426
Consumer Public Power District, Beatrice, Neb.	75	43	573
Rural Cooperative Power Association, Elk River, Minn.	22	12	546
Commonwealth Edison Co., Dresden, Ill.	180	60	333
Consolidated Edison Co. of N.Y., Indian Point, N.Y.	236	90	381
Totals	847	380	450

With respect to the starting point for capacity costs, (that is, dollars per kilowatt), all currently announced large-scale plants expected to be working by 1960 are considered (Table 1). Their capacities (*1*) and the most recently revised estimates of their costs (*4, 7*) are listed, and from the totals given, a capacity cost of about $450 per kilowatt, on the average, is derived.

Referring now to Fig. 2, we see, using point *A* (847,000 kilowatts and $450 per kilowatt in 1960) as the origin of the upper cost line, that this line intersects the 100,000 kilowatt capacity line at $950 per kilowatt. This can be taken to refer to the Shippingport plant, which is expected to cost about $700 per kilowatt. Accordingly, a second line, parallel to the first, was drawn through this value to indicate a lower possible cost range.

A similar procedure was used in obtaining the two bus-bar cost lines. Point *B* was obtained from the data given in Table 2. Fixed costs are computed by taking 10 percent per annum of the $450 per kilowatt investment cost and then converting to mills per kilowatt-hours by noting that in recent years the ratio of kilowatt-hours to kilowatts has remained steady at about 4500 for the whole utility industry (*8*). The lower cost line was similarly derived, except that the maximum McKinney panel figures of 4 and 2 mills, respectively, were used for fuel and operating costs and the figure 15.5 mills, based on $700 per kilowatt (1958), was used for fixed costs.

As noted, Fig. 2 also indicates when these power levels and, hence, these costs will be applicable. Recent evidence indicates, moreover, that these predictions may be quite realistic. Sir John Cockroft (*9*) has estimated that British nuclear power would cost 8 mills per kilowatt-hour in 1960 and that U.S. costs would be about 50 percent greater—that is, 12 mills per kilowatt-hour. This is point *C* in Fig. 2, which is seen to fall within the range of the estimate. Similarly, Untermyer (*10*) has cited the experience of the 5000-kilowatt plant of the General Electric Company in Vallecitos, California. Costs there were about $600 per kilowatt at nominal capacity, but the plant could be operated at up to double load if its A.E.C. license permitted; hence this figure must be regarded as an upper limit. Even so, $600 per kilowatt in 1957–58 is well below the lower cost line (point *D*). The nuclear cost levels must now be set against cost developments in conventional power.

Projection of Conventional Power Costs

Present conventional steam power costs are about $150 per kilowatt capacity and the mills per kilowatt-hour range from about 4 to 10 in most cases, being distributed in a rather skewed fashion between these limits, with the mode (that is, the most common level) at about 4.5 mills (*11*).

Both Davis and Roddis (*1*) and the

Table 2. Computation of point B, Fig. 2 (*2*).

Item	Cost (mills/kwh)
Fuel	3.5
Operating and maintenance	1.1
Fixed costs	10.0
Total	14.6

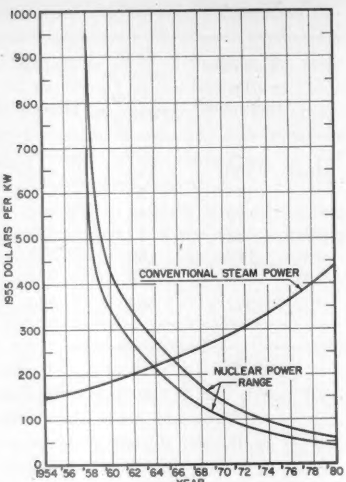


Fig. 3. Projected alternative power costs, 1955–1980.

McKinney panel (2) expect this cost pattern to continue. There is recent evidence, however, which calls into question the validity of this estimate. In a study of central station steam equipment costs, Watkins (12) has developed a method for predicting the requirements in decreased station heat rate which must be met in order to keep future power costs at their present level. From this, it is found that, in order to maintain present costs through 1967, a net steam rate efficiency gain of 3000 British thermal units per kilowatt would have to be realized. However, the McKinney panel expects an improvement of only about 800 British thermal units per kilowatt in that period, which, according to Watkins, would be just sufficient to neutralize a very modest concurrent rise in fuel costs from \$6.25 to \$7 a ton. Boiler costs may therefore rise to \$6 per pound of steaming capacity as compared with \$3.57 in 1955. Boiler costs are a key determinant of power plant cost, and this factor may therefore be applied to all elements of the investment need, particularly since other equipment must be suitable for operation at the same pressure, temperature and efficiency level as the boiler and therefore follows a similar cost structure. Accordingly, the investment cost in 1967 may be expected to be

$$\$150 \times (6/3.57) = \$252 \text{ per kw}$$

Bus-bar costs are currently made up of 54 percent fixed charges, 36 percent fuel cost, and 10 percent operating and maintenance (6). Applying these percentages to the 4.5-mill-per-kilowatt-hour rate, we get the breakdown given in Table 3.

The range will be from 5.75 to 14.35 mills per kilowatt-hour, obtained as in the table. The operation and maintenance cost is expected to increase in accordance with the observed increase in average hourly earnings, according to data of the Bureau of Labor Statistics. The values were extrapolated to 1980.

Watkins' analysis also points out that, in order to keep within these costs, further rises in unit size, operating temperatures, and pressures must be countenanced and that size, particularly, is likely to present major operating and power market problems. The 750,000- or 1-million-kilowatt units envisaged in this connection would be too large, relative to total system capacity, for any but the largest half-dozen utilities in the country. Even there, present restrictions on the relation between largest single units and system capacity would have to be revised upward. This has not been specifically considered here, but it seems probable that, since not all conventional plants of 1967 will be able to be of this "optimum" size, many will be more expensive still. Watkins' data for boiler and equipment cost and, in fact, a study of recent trends of machinery prices suggest that this viewpoint may prove correct.

Comparison of the Two Methods

It is now possible to summarize the results of the computations and thus to compare the cost projections for the two methods of power generation. Figure 3 indicates projected movements of the costs of power station capacity, and it will be observed that the break-even zone

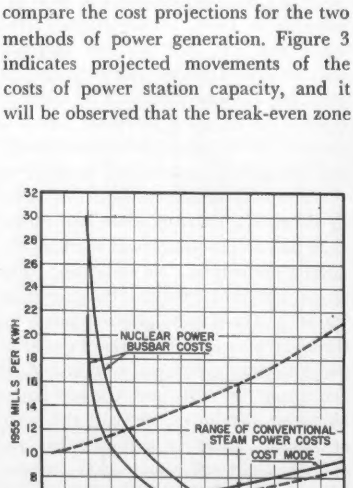


Fig. 4. Projected alternative power plant capacity costs, 1955–1980.

Table 3. Typical present costs for conventional steam power production and projections for 1967.

Item	Costs, 1958 (mills/kwh)	Anticipated fractional increase	Costs, 1967 (mills/kwh)
Fixed charge	2.43	6/3.57	4.08
Fuel	1.62	7/6.25	1.82
Operation and maintenance	0.45	155/124	0.56
Totals	4.50		6.46

occurs between 1964 and 1966. Figure 4, on the other hand, shows power costs in mills per kilowatt-hour, and it is seen that the break-even zone is much wider. The cost range of conventional power, as illustrated, is largely due to fuel cost differentials, though, as noted, economics of scale is becoming an increasingly great problem in some areas. At any rate, it appears from Fig. 4 that, beginning in 1960, nuclear power will begin to compete with conventional plants of high cost and that, by 1968, even the highest cost of nuclear power, as projected here, will be about the same as the lowest costs of conventional steam power in that period. It will also be observed that in this analysis there actually is a break-even point and that nuclear and conventional steam power will not enjoy a prolonged period of equality of cost. Such predictions of sustained cost equality have also appeared in other estimates of nuclear and conventional power costs (1, 2). The method used here, however, points to an early and sharp cost distinction favoring nuclear power.

In Fig. 2, on which the present estimates of nuclear power costs are based, a certain rate of nuclear power introduction was used which is part of a rather more conservative forecast than the present one. It may be that, if the cost trends illustrated here hold true, the rate of introduction and of contribution to United States power needs may actually be more rapid than is here indicated, particularly in the latter part of the break-even zone of Fig. 4. This, in turn, might have the effect of accelerating the cost decline.

It may be objected that the converse also holds true—that if, for some reason, the introduction of nuclear power in the United States were to proceed at a much slower rate than that predicted by Davis and Roddis, the costs would also decline more slowly. This, however, fails to take into account the fact that technology is

indivisible and international and that the large-scale work on power reactors now in progress, especially in Europe and the U.S.S.R., will bring with it declines in costs quite similar to those illustrated here. In the case of Europe, rising costs of coal and reluctance to depend on Middle East oil furnish powerful incentives for introducing nuclear power. Thus, Cockroft's cost prediction, already cited (*9*), actually means that in England nuclear power will cost about 10 percent more than the national *average* in 1960, the same in 1963, and 30 percent less by 1970. This timing is quite similar to that illustrated in Fig. 4.

Any substantial acceleration of atomic power usage by the early 1960's would actually require advance planning now. This does not appear in the offing, however, judging from current rather "bearish" industry comments in the technical press. It would seem, then, that we may anticipate a gradual increase in the real cost of power, followed eventually by a decline, as nuclear power really effects its commercial "breakthrough."

In the present analysis, only steam-cycle nuclear plants have been considered. No attempt has been made to estimate the costs of direct generation fission plants or of fusion power, which would probably also circumvent the steam cycle. Their feasibility is as yet not proven but, especially in the case of fusion power, may well be demonstrated in time to hasten the demise of the coal-fired steam plant even more.

References and Notes

1. W. K. Davis and L. H. Roddis, "A Projection of Nuclear Power Costs," in *Prospects for Economic Nuclear Power* (National Industrial Conference Board, New York, 1957), p. 21.
2. *Background Material for the Report of the Panel on the Impact of the Peaceful Uses of Atomic Energy to the Joint Committee on Atomic Energy* (Government Printing Office, Washington, D.C., 1956), vol. 2, pp. 10–18.
3. W. A. Raborg, *Aero Dig.* **65**, No. 5, 17 (1952); F. J. Andress, *Harvard Business Rev.* **32**, No. 1, 87 (1954).
4. F. J. Fairman, *Elec. World* **148**, No. 17, 44 (1957).
5. A. Puishes *et al.*, *Comparison of Calder Hall and PWR Reactor Types*, AECU-3398 (1 March 1957), p. 4.
6. V. F. Estcourt, *Trans. Am. Soc. Mech. Engrs.* **75**, 343ff. (1953); see also discussion *ibid.*
7. *Business Week* No. 1467, 48 (12 Oct. 1957).
8. Federal Power Commission, *Statistics of Electrical Utilities, Class A and B* (Washington, D.C., 1955).
9. Quoted in "Fusion reactor gains in Britain," *New York Times* (17 Oct. 1957).
10. S. Untermyer II, "Vallecitos Developmental Boiling Water Reactor," Paper 57-AIF-111 (Atomic Industrial Forum, New York, 28–31 Oct. 1957).
11. J. Gueron *et al.*, *The Economics of Nuclear Power* (McGraw-Hill, New York, 1957), p. 203.
12. G. E. Watkins, "Cost determinants of process plant design," unpublished doctoral dissertation, Columbia University, 1956.
13. H. Weisberg, *Combustion* **24**, No. 8, 45 (1953).

Albert Prescott Mathews, Biochemist

The death of A. P. Mathews in his 86th year, on 21 September 1957, has removed one of the last of those American scientists who came under German influence during the latter part of the 19th century. Although Mathews was granted his Ph.D. degree by Columbia University in 1898, he had previously (1895–1897) studied and traveled in Europe. At Marburg, he came under the influence of the German biochemist and Nobel prize-winner Albrecht Kossel, who greatly stimulated him, arousing his interest in the nucleus and in the physicochemical aspects of biology.

Mathews' early work had to do with the physiology of secretion, but he soon turned to a more general study of living cells. As a research scientist, Mathews published about one hundred papers on a wide variety of biochemical and biophysical subjects. Of his five books, three are biochemical in content—*Physiological Chemistry* (1915), *Principles of Biochemistry* (1936), and *Vitamines, Minerals and Hormones* (1937). The other two—*The Nature of Matter, Gravitation and Light* (1927) and *Gravitation, Space-time and Matter*—show his interest in philosophical subjects, an interest which permeated some of his shorter works. The book on *Physiological Chemistry*, first published in 1915, was the principal American text for nearly three decades. The sixth revised edition appeared in 1939. It not only served to present the properties of the chief groups of biochemical compounds but approached the subject from the viewpoint of the physical chemist. The book appeared at just the right time to inspire many a student to decide on a career in this rapidly growing and important subject.

Mathews was born in Chicago on 26 November 1871. His choice of biochemistry for a career was not a result of an early interest in either biology or chemistry. His father was a writer and music critic for the old *Chicago Daily News* at the time the paper was edited by Melville Stone, and Eugene Field, the poet, was a columnist. From his early years, Mathews was exposed to the best in music. As a very young boy he was taken to concerts and to the opera by his father, and he thus developed a taste for and love of music, which gave him the greatest pleasure in later life. Many of his friends were not aware of this aspect of his character but thought of him as being purely a scientist, a teacher, and a philosopher.

Mathews finished high school at the age of 15 and was ready to enter the Massachusetts Institute of Technology, where he intended to study electrical engineering. At M.I.T. he came under the influence of William T. Sedgwick, whose textbook *General Biology*, written in collaboration with E. B. Wilson, first appeared in 1886 and was widely used in schools and colleges. This influence undoubtedly changed the direction of Mathews' career from the purely physical to the biological sciences. He was no doubt influenced by his grandfather, a physician, with whom he spent his summers. The two discussed medical problems, and young Mathews went the rounds of patients with his grandfather. Thus, his medical, biological, and chemical interests, and his strong leaning toward physical chemistry determined that Mathews should become, first, instructor and then assistant professor at the Medical School of Tufts College, later at Harvard Medical School. He went to the University of Chicago in 1901, finally becoming head of the department of physiology, later head of physiological chemistry, a position that he held from

1907 to 1918. During World War I he served as captain in the Quartermaster Corps for a short time. In 1918 he accepted the position of Andrew Carnegie professor of biochemistry and chairman of the department at the University of Cincinnati—a position held until his retirement in 1939.

Mathews' Ph.D. thesis at Columbia University was entitled "The Physiology of Secretion," and was published in 1898; in 1895 he was coauthor, with E. B. Wilson, of a long paper on "Maturation, Fertilization and Polarization of the Echinoderm Egg"—a title indicating his interests in biological matters. Over the next 20 years his studies dealt with salt effects in cells and with the physical chemistry of living systems; for these studies he used fish, sea urchin, and starfish eggs as material. This work was carried out at the Marine Biological Laboratory at Woods Hole, Massachusetts, where Mathews spent his summers for many years, as an associate and intimate friend of the great biologists who made that laboratory renowned throughout the world. He lived with his charming wife and daughter in his cottage on Buzzards Bay Avenue, next to that of T. H. Morgan and across the street from that of E. B. Wilson, while E. G. Conklin and G. N. Calkins lived near by. Jacques Loeb, whose books *The Mechanistic Conception of Life* and *Dynamic of Living Matter* had so much influence on the men of that day, lived not far away. Woods Hole was just the place for a man of Mathews' broad interests, and the group benefited immensely from his new and stimulating ideas. He was a member of the board of trustees of the laboratory from 1906 until his death.

Mathews' textbooks illustrate his love of exposition, and it is as a teacher and a stimulator of young minds that he will be best remembered. His students all think of him with very deep and real affection, grateful for his advice in scientific matters and the encouragement he gave them to adopt careers in medicine and science. It was not only in professional but also in personal matters that Mathews and his wife were so helpful and sympathetic. Up to the time of his death he followed the later life of his students with the greatest interest. A total of 66 master of science degrees and 44 doctor of philosophy degrees were granted under his direction.

At the time of his death, Professor and Mrs. Mathews had been married for 62 years. She was devoted to him, and the family life was a particularly happy one. Mathews was a fine specimen of mankind—tall and handsome, with that athletic look that befits a person of character and determination. I can still see him, walking briskly with great strides along the streets of Woods Hole, with his head held high and a keen penetrating look in his blue eyes, as if he were about to lay bare the secrets of the universe. His convictions were strong and his ideals high. Science, particularly biochemistry, has lost a great teacher and a dedicated seeker of new knowledge.

E. Newton Harvey
Department of Biology, Princeton University, Princeton, New Jersey

News of Science

Improving High School Education

At a meeting of high school principals and teachers in Washington on 23 March, three of the nation's leading scientists and educators offered suggestions for improving high school education. The meeting was part of the fiftieth anniversary celebration of St. Alban's School for Boys at the Washington Protestant Episcopal Cathedral.

Merle A. Tuve of the Carnegie Institution of Washington, James R. Killian, Jr., President Eisenhower's Special Assistant for Science and Technology, and Rear Admiral Hyman G. Rickover of the Navy's nuclear reactor program agreed on the need to raise the standards that all high school graduates must meet. Following are excerpts from the three speeches; the excerpts set forth some of the principal suggestions offered.

Tuve advises making teaching more attractive. "It is exceedingly difficult nowadays to attract into teaching any student who has completed a good, solid, college major in physics or chemistry or mathematics, because there are so many interesting and attractive jobs elsewhere, with good pay, and also because most states and local communities have laws which require all prospective teachers to have taken many semester hours of educational psychology, practice teaching, and similar subjects.

"If we really want to do something about improving secondary education here is one direct and simple thing that will surely have great effect in strengthening our schools: We can go after our local school boards and our own state legislatures to change the laws which now restrict teacher certification to the products of the courses in education.

"There are two other actions local groups can take in any community which also will help greatly to improve secondary education.

"The idea that our secondary school teachers should be working with students five or six hours a day for five days a week, plus some late afternoons and many evenings on P-T. A. and other school assignments, denies these teachers any status as scholars. A practical action for a community group is to insist that the professional teacher be given some time to himself for his own scholarship. We can hire clerks and stenographers and specialists in education to handle these countless chores and public relations activities.

"The other action relates to salaries; this is important but not as vital as the first two points I have made. There should be provision for much greater spread of salaries, and a significant part of this spread should be for merit in teaching and scholarship, not only for longevity and for credits and more degrees from schools of education."

Killian scores attitude of take-it-easy. "If we are to have better science education, we must have better over-all education and if we are to have better education, we must have a shift in values so that intellectual interests and performance are not played down and socially denigrated. We must cultivate in all of our education a distaste for the take-it-easy and anti-intellectual attitudes and a positive taste for what is excellent in intellect and spirit. . . .

"In the development of our public school system, we have concentrated in recent years on making it universally available and of the greatest help to the

greatest number. The next phase—the next great mission of our educational system—should be to introduce more extensively into our system of mass education the opportunities and means for differentiation in order to permit the fullest encouragement and development of our high talent.

"We need to fight the mucker pose that it is smart to be anti-intellectual. We must set greater store by intellectual achievement and the senses of the first-rate in all education."

Rickover stresses importance of factual knowledge. "We should not have to support schools if we want no more than "adjustment" of children to life as it is. A child is being properly educated only when he is learning to become independent of his parents. We have schools because we know that in today's world everyone is daily called upon to make decisions for which he needs a background of general knowledge, not obtainable merely by "learning through living." To acquire such knowledge, fact upon fact, takes time and effort. If we try to spare our children mental effort and to protect them against disappointments or personal failures through flunking exams, we send them ill prepared into a competitive world. The degree of ignorance which a democracy can tolerate varies in inverse ratio to the advance of the nation toward higher cultural and scientific levels.

"Our elementary and secondary education must, thus, provide first, for the average and below-average student, a sufficiently broad terminal education to fit him into a modern technological society; and second, for the talented student, it must provide a solid underpinning for subsequent professional education. Neither of these two objectives is achieved in the majority of American public school systems. Unlike all other Western countries of similar civilization, we lack a national standard for curricula, for school-leaving examinations, for diplomas, or for teacher qualifications. There is a wide variety in the school systems of different states, even for different cities in the same state."

Radiation Hazards Program

A program at New York University–Bellevue Medical Center concerned with hazards of radiation as they are to be found in the environment has been made possible through a $500,000 grant from the Rockefeller Foundation. The grant, for use during the 10-year period beginning January 1958, will provide salaries for additional staff required for development of a program of both research and teaching within a new unit.

The unit's work will be directed by Norton Nelson, head of the center's Institute of Industrial Medicine and professor and chairman of the department of industrial medicine in N.Y.U. Post-Graduate Medical School. An important contribution to the effectiveness of this program will come from the recently established arrangement between the Institute of Industrial Medicine and the U.S. Atomic Energy Commission's Health and Safety Laboratory which provides a basis for cooperative research and teaching between the two units. The Health and Safety Laboratory is under the direction of S. Allan Lough. Members of the Health Safety Laboratory have for a number of years served on the faculty of the institute.

Grants, Fellowships, and Awards

Botany. The Committee on the Darbaker Prize of the Botanical Society of America will accept nominations for an award to be announced at the annual meeting of the society in 1958. Under the terms of the bequest, the award is to be made for meritorious work in the study of algae. Nonmembers of the society are eligible. The committee will base its judgment primarily on the papers published by the nominee during the last two full calendar years previous to the closing date for nominations. At present, the award will be limited to residents of North America. Only papers published in the English language will be considered. Nominations for the 1958 award, accompanied by a statement of the merits of the case and by reprints of the publications supporting the candidacy, should be received before *1 May* by the chairman of the committee, George F. Papenfuss, University of California, Berkeley.

Cardiological Reporting. The American Heart Association has announced the opening of the sixth annual competition for the Howard W. Blakeslee Awards for outstanding reporting in the field of heart and blood vessel diseases. The association's Awards Committee will make its selections from among newspaper and magazine articles, books, radio and television programs, and films published or produced between 1 March 1957 and 28 February 1958. The deadline for entries is *1 May.* The awards which carry an honorarium of $500 each, will be presented in the fall. Entry blanks and rules folders may be obtained from local Heart Associations or from the American Heart Association, 44 E. 23 St., New York 10, N.Y.

Earth Sciences. The Earth Sciences Program of the National Science Foundation is now receiving proposals for research grants that will be made in October 1958. The deadline for the receipt of proposals for work to begin in the fall or early winter is *15 May.* There are no formal application blanks, but a foundation pamphlet describes the method of making application and outlines the information needed in a proposal. This pamphlet may be obtained by writing to the National Science Foundation, Washington 25, D.C. Attention: Earth Sciences Program.

Use of Satellites for Research in Life Sciences

Methods by which artificial earth satellites can be used to further basic research in the life sciences will be the subject of a symposium, 14–17 May, to be sponsored jointly by the National Academy of Sciences, the American Institute of Biological Sciences, and the National Science Foundation. Attendance at the symposium, which will probably take place in Washington, D.C., will be by invitation only; invitations will be sent to about 200 biologists, biochemists, biophysicists, psychologists, medical scientists, and others. About 30 papers will be presented.

A steering committee—composed of representatives of the three sponsoring organizations and of appropriate scientific disciplines—has announced three main objectives: (i) to exchange information concerning the technical feasibility and scientific importance of various experiments with living organisms in the satellite environment; (ii) to discuss methods and techniques for conducting such experiments, including associated laboratory work; and (iii) to stimulate thinking that will lead to a sound program of research in the life sciences through the use of earth satellites.

Geology Neglected?

The American Geological Institute has released a statement entitled "Government Weakness Apparent in Mineral Security Area" that includes the following comments:

"The American Geological Institute is deeply concerned over the current neglect by the Federal Government of problems relating to our national mineral security. Minerals and the mineral fuels are the raw material base on which our great scientific and technologic advances have been founded. In our current zest to conquer space, the government is unfortunately showing little concern over a strong mineral research policy to match growth and needs of science and technology.

"Dr. Robert C. Stephenson, Executive Director of the American Geological Institute, a federation of fourteen scientific societies in the area of the geological sciences, representing over 30,000 geoscientists, has recently, by letter, brought

this to the attention of Dr. James R. Killian, Scientific Advisor to the President, Dr. Alan T. Waterman, Director of the National Science Foundation, [and others]. . . .

"The Administration and Congress have declared themselves all out for science and technology and are voting vast sums for research. Yet, the U.S. Geological Survey, one of the oldest and most respected government research organizations, is facing in the next fiscal year beginning July 1 a material decrease in the funds available for its research programs in the mineral resources field.

"Science is not divisible into several exclusive categories because it is a cross-fertilization of many skills. . . . In government, the geological scientists charged with our mineral research efforts are being relegated to the role of 'second rate scientists' along with biologists and other minority groups of scientists who have not benefited from pay increases granted most scientists and engineers. The high morale of geologists in government service is being adversely affected by this discriminatory practice and a general loss of scientific prestige is resulting. . . .

"The American Geological Institute urges that our Nation take positive and immediate steps to correct the current imbalance plaguing the geological scientists and geological research. Our mineral future must be secure if science and technology are to advance."

El Salvador's Tropical Institute

The Tropical Institute of Scientific Research in San Salvador was established by the University of El Salvador in 1950 to encourage research in the seven faculties of the university—law, medicine, dentistry, pharmacy and chemistry, engineering (civil, architectural, agronomic, and electrical-mechanical), economics, and humanities (philosophy, psychology, literature, and languages)—and to provide facilities for the use of visiting scientists desiring to study the tropical environment.

El Salvador is the most densely populated of the five Central American republics, having compressed within its 8600 square miles more than 2 million inhabitants. The country is principally of volcanic origin, with one volcano still active. The volcanic character of the soil contributes to its high fertility. The principal product of the country is coffee, which provides almost 80 percent of the national income. The country's economy is sound. Its monetary unit, the colon, has for 25 years remained at a fixed value of $0.40 U.S.

The climate of El Salvador ranges from hot in the coastal plains to moderately cool in the highlands. The institute is located in University City on the outskirts of the country's capital, San Salvador. This city, which has a population of more than 200,000 inhabitants, is situated on a plain some 2000 feet above sea level. Its climate is pleasant, with a mean annual temperature of approximately 72°F with extremes of from 46° to 96°F. It is 14° north of the equator and 89° west of the Greenwich meridian.

Almost all of the research conducted by the institute is under the supervision of visiting scientists sent to the country by institutions of learning and research in the United States and Europe. Before a visitor is accepted by the institute, he submits a plan of the type of study he wishes to undertake. If his proposed research is of a nature which will be useful not only to him but to El Salvador, his application is accepted. Board and room are provided without charge at the institute's boarding house, the visitor is given laboratory facilities, transportation, reference materials, and other necessary assistance. Many public and private institutions cooperate with the institute in helping the visitors carry out their research programs. However, if very expensive equipment of limited usefulness is needed, the visitor or his sponsor is asked to provide this as a loan to the institute during the period that the visitor is in residence. When the proposed research requires more than 1 year to complete, the institute pays transportation for the visiting scientist to El Salvador and return and also provides him with $30 per month for personal expenses. Research assistants are usually Salvadorean high-school graduates interested in research who, by working with the visiting scientists, prepare themselves for research careers or for scholarships abroad.

The principal research conducted by the institute since its foundation has been in the fields of zoology, botany, geology, soil sciences, hydrology, meteorology, archeology, anthropology, economics, tropical medicine, and chemistry. In return for the facilities offered by the institute, visiting scientists are asked to submit complete reports of the studies; if specimens have been collected, the institute expects to receive a complete set of the materials collected, properly classified.

Usually from six to eight visitors are in residence at the institute, although at times the entire capacity of the boarding house (14 visitors in eight guest rooms) has been in use.

Among the works published in book form by visitors of the institute are: *Birds of El Salvador*, by Austin L. Rand and Melvin A. Taylor of the Museum of Natural History, Chicago; *Farinosa of El Salvador*, by Otto Rohweder, University of Hamburg; *Amphibia and Reptiles of El Salvador*, by R. Mertens, Frankfurt-am-Main, Germany. The institute publishes a quarterly, *Communicaciones del Instituto Tropical de Investigaciones Científicas de la Universidad de El Salvador, C.A.* Much of the research carried on by the visiting scientists is reported in this journal, especially when the reports are not of book length.

The institute is anxious to receive applications from scientists and scientific institutions who desire to carry on tropical research in any scientific field. More detailed information may be secured by writing to the Director General, Instituto Tropical de Investigaciones Científicas, Apartado 740, San Salvador, El Salvador, Central America.

ARISTIDES PALACIOUS

Tropical Institute of Scientific Research, University of El Salvador

Bureau of Standards and National Academy Advisory Program

The National Bureau of Standards and the National Academy of Sciences–National Research Council have announced an expanded plan for coordination of the bureau's technical advisory committee program by the Academy–Research Council in cooperation with a number of the major professional scientific societies of the United States. The NBS advisory committee program grew out of the recommendations of a committee appointed by the Secretary of Commerce in 1953. Since that time, advisory committees appointed by various professional scientific societies have helped to keep the bureau informed of the needs of the nation's scientific and technological community and have evaluated the bureau's work in areas of interest to their professions. At the same time they have provided an effective link whereby the scientists and engineers of the country have gained increased awareness of the scientific contributions and services available from the bureau.

The new plan for coordination of these advisory activities by the Academy–Research Council will strengthen the current program by allowing more complete coverage of the bureau's diversified research activities, and by providing for the coordination of recommendations from the various professional interests which the bureau serves.

Under the new arrangement, the scientific societies will nominate representatives from among their membership to serve as advisers to the bureau. From the base provided by these society delegations, the Academy–Research Council will assemble a number of advisory panels, each of which will have respon-

sibility for evaluating a particular segment of the bureau's work. Thus, certain NBS activities—such as building technology, which does not fall within the scope of any one professional society—can now be served by advisory panels staffed from various societies. The panels will report at least once a year on the status of bureau activities under their cognizance. These reports will form the basis for an integrated annual report by the Academy–Research Council to the bureau.

Selection of the National Academy of Sciences–National Research Council to administer and coordinate the advisory program will insure a broadly-based, independent evaluation of the bureau's work. Since it maintains well-established ties with the professional scientific societies of the country, the Academy–Research Council is uniquely qualified to assist the bureau in this new role.

International Atomic Energy Agency Has Offers of Contributions

The International Atomic Energy Agency has announced in Vienna that by the end of January 1958 nine member states had officially communicated to it offers of fissionable materials, source materials, radioactive isotopes and special materials for reactors, and fellowships and training facilities for atomic energy programs to be carried out under its auspices. The offers are from Canada, Ceylon, India, Norway, Portugal, the Union of South Africa, the U.S.S.R., the United Kingdom, and the United States.

The prices and conditions on which the materials are to be made available to the agency have yet to be determined. The source materials and fissionable materials will for the present remain under the control of the countries of origin and will be delivered only after agreements have been concluded between the agency and the member states concerned.

Contributions have also been offered to the $250,000 fellowship fund to which member states were invited by the first General Conference to subscribe. Several member states have at the same time placed at the disposal of the agency fellowships and training facilities to be taken up in the offering countries. In addition, the United States has announced its intention of presenting the agency with the gift of a technical library.

Proposed Legislation

S 3110. Establish Commission on Establishment of a United States Academy of Science. Potter (R-Mich.). Senate Armed Services.

S 3119. Amend National Science Foundation Act in order to revise authority to grant scholarships and fellowships under provisions of such act. Mansfield (D-Mont.). Senate Labor and Public Welfare.

HR 10180. Amend National Science Foundation Act of 1950 to encourage training of additional engineers and scientists and expansion of facilities for engineering and science education by providing scholarships and fellowships for engineering and science students. Sikes (D-Fla.). House Interstate and Foreign Commerce.

S 3089. Provide for holding a White House Conference on Aging to be called by President of U.S. before 31 December 1958, to be planned and conducted by Special Staff on Aging of the U.S. Department of Health, Education and Welfare with assistance and cooperation of other agencies of that Department and other Departments and agencies represented on Federal Council on Aging; assist several States in conducting similar conferences on aging prior to White House Conference on Aging. McNamara (D-Mich.), Humphrey (D-Minn.). Senate Labor and Public Welfare.

S 3126. Create Department of Science and Technology; establish National Institutes of Scientific Research; authorize program of Federal loans and loan insurance for college or university education in physical or biological sciences, mathematics, or engineering; authorize establishment of scientific programs outside U.S. Humphrey (D-Minn.), McClellan (D-Ark.), Yarborough (D-Tex.). Senate Government Operations.

S 3156. Provide for expansion of certain programs for advance education for teachers in science and for establishment of certain programs for advance education for teachers in the humanities. Flanders (R-Vt.), Bricker (R-Ohio.). Senate Labor and Public Welfare.

S 3157. Establish federal scholarship program in order to assist promising students to obtain college and university undergraduate educations. Flanders (R-Vt.), Bricker (R-Ohio.). Senate Labor and Public Welfare.

S 3179. Authorize federal assistance to states and local communities in financing an expanded program of school construction to eliminate national shortage of classrooms. Kennedy (D-Mass.). Senate Labor and Public Welfare.

S 2938. Amend Internal Revenue Code of 1954 to allow additional income exemption for an individual who is a student at an educational institution above secondary level. Frear (D-Del.). Senate Finance.

S 3180. Establish a U.S. Department of Science and prescribe functions thereof. Kefauver (D-Tenn.). Senate Government Operations.

S 3187. Strengthen national defense, advance cause of peace, and assure the intellectual pre-eminence of the U.S., especially in science and technology, through programs designed to stimulate their development. Hill (D-Ala.) and 26 other senators.

HR 10278. Encourage and assist in expansion and improvement of educational programs. Kearns (R-Pa.). House Education and Labor.

HR 10290. Amend Outer Continental Shelf Lands Act in order to provide that revenues under provisions of such act be used as grants-in-aid of primary, secondary and higher education. Udall (D-Ariz.). House Judiciary.

HR 10293. Establish a national scientific research reserve fund. Dawson (D-Ill.). House Interstate and Foreign Commerce.

HR 10381. Strengthen national defense, cause of peace, and assure the intellectual pre-eminence of U.S. especially in science and technology, through programs designed to stimulate their development. Elliott (D-Ala.). House Education and Labor.

HR 10404. Amend Federal Food, Drug, and Cosmetic Act for protection of public health, by prohibiting new food additives which have not been adequately pretested to establish their safe use under conditions of their intended use. Williams (D-Miss.). House Interstate and Foreign Commerce.

HR 10266. Extend for 1 year certain programs established under Domestic Tungsten, Asbestos, Fluorspar, and Columbium-Tantalum Production and Purchase Act of 1956. Aspinall (D-Colo.). House Interior and Insular Affairs.

S 3216. Authorize Federal assistance to States and local communities in financing an expanded program of school construction to eliminate national shortage classrooms. Javits (R-N.Y.). Senate Labor and Public Welfare.

HR 10454. Establish a scholarship program to train scientists and technicians; provide scholarship beneficiaries be obligated to serve in Armed Forces upon completion of their education. O'Konski (R-Wis.). House Education and Labor.

HR 10456. Amend National Science Foundation Act of 1950 in order to provide for certain educational programs. Price (D-Ill.). House Interstate and Foreign Commerce.

HR 10598. Amend title IV of Housing Act of 1950 to authorize loans under college housing loan program for construction of science buildings and libraries at educational institutions. Carrigg (R-Pa.). House Banking and Currency.

S 3281. Amend Housing Act of 1950 to provide for loans to colleges and universities for science equipment and facilities. Thye (R-Minn.). Senate Banking and Currency.

S 3311. Authorize assistance to states

and local communities in remedying the inadequacies in number of their teachers and teachers' salaries and shortage in classrooms. Murray (D-Mont.), Mansfield (D-Mont.), Cooper (R-Ky.), Morse (D-Ore.), McNamara (D-Mich.), Langer (R-N.D.). Senate Labor and Public Welfare.

HR 10768. Strengthen national defense, advance cause of peace, and assure intellectual pre-eminence of U.S., especially in science and technology, through programs designed to stimulate development and increase number of students in science, engineering, mathematics, modern foreign languages, and other disciplines; provide additional facilities for teaching thereof; promote development of technical skills essential to national defense; assist teachers to increase their knowledge and improve their effectiveness. Perkins (D-Ky.). House Education and Labor.

HR 10842. Encourage expansion of teaching and research in education of exceptional children through grants to institutions of higher learning for training of personnel with advanced professional skills in special education. McGovern (D-S.D.). House Education and Labor.

S 3294. Authorize Secretary of Commerce to enter into contracts for conduct of research in field of meteorology and authorize installation of Government telephones in certain private residences. Magnuson (D-Wash.) (by request). House Interstate and Foreign Commerce.

HJ Res 545. Provide for construction by Secretary of Interior of three full-scale demonstration plants for production, from sea or other saline waters, of water suitable for agricultural, industrial, municipal, and other beneficial consumptive uses. Roosevelt (D-Calif.). House Interior and Insular Affairs.

Civil Service Salary Increases

The Civil Service Commission has authorized an increase in the minimum entrance pay rates for additional shortage-category jobs in the physical and biological sciences as well as for mathematical statisticians. Positions affected are in the following categories: astronomers (GS-1330 series), oceanographers, physical (GS-1360 series), pharmacologists (GS-405 series), mathematical statisticians (GS-1530 series), forest products technologists (GS-1390 series), and geophysicists, exploration (GS-1313 series). The new rates for these jobs, effective 24 February, are: GS-6, $4890; GS-8, $5780; GS-9, $6250; GS-10, $6725; GS-11, $7465; GS-12, $8645; GS-13, $10,065; GS-14, $11,395; GS-15, $12,690; GS-16, $13,760; and GS-17, $14,835.

The action will result in a pay increase aggregating some $320,000 a year for approximately 680 Federal employees already on the rolls. Individual raises will range from $135 to $1080 a year. An additional $106,780 will go to pay the salaries of 150 new employees expected to be added to the rolls in the next 12 months.

The Civil Service Commission expects early completion of current studies of other shortage-category jobs in biological and other scientific areas to determine any further need for increases to help the Government's recruitment efforts.

Scientists in the News

JAMES W. COLE, professor of chemistry at the University of Virginia, has been named dean of the division of general studies and services (extension division). He will succeed GEORGE W. ZEHMER, who will retire 31 August as director of the extension division. Zehmer, who has headed the extension division since 1925 and who served as dean of the summer school from 1935 to 1947, will continue to teach in the School of Education.

DONALD R. HAMILTON, a nuclear physicist and professor of physics at Princeton University, has been named dean of the university's graduate school, effective 1 July. He succeeds HUGH S. TAYLOR, who has reached the compulsory retirement age of 68.

ROBERT A. COOKE, founder in 1918 of the world's first allergy clinic, the Hay Fever and Asthma Clinic at New York Hospital, was recently honored at a dinner given for him by the New York Allergy Society. Cooke, at present director of the Institute of Allergy at Roosevelt Hospital, N.Y., was cited for his contributions "to medicine and human welfare . . . in elaborating the whole field of allergy."

The first Walter C. Russell Memorial Lecture will be given by D. P. CUTHBERTSON, director of the Rowett Research Institute, Aberdeenshire, Scotland, on "The Metabolic Reaction to Trauma" on 21 April at 4 P.M. at Douglass College, Rutgers University, New Brunswick, N.J. Russell served Rutgers for 29 years previous to his death in 1954 as professor of agricultural biochemistry. He was also first dean of the Rutgers Graduate School.

HERSCHEL LEIBOWITZ, psychologist at the University of Wisconsin, has returned to the university after a year's research leave at the University of Munich and the Max Planck Institute for the Physiology of Behavior. He comments that scientists at the Max Planck Institutes, of which there are more than 40, have no other duties but research and need not devote time to routine administrative responsibilities.

ALBERT J. FREY, vice president in charge of the technical department of Hoffmann-La Roche Inc., Nutley, N.J., has retired after 42 years of service. He plans to do consulting work in chemical engineering. Frey is succeeded by RAETO SCHETT, who has been his assistant for the past 2 years. Frey, who was born in Switzerland, received his Ph.D. in colloid and physical chemistry at the University of Berne in 1914. In 1915, he joined Roche in Basle, Switzerland, as a research chemist. In 1920, he was named production manager, a position he held until 1941, when he went to Nutley as manager of the Roche technical department. In 1944, Frey was elected vice president in charge of the technical department.

RICHARD I. CONDIT, formerly president of the Broadview Research Corporation, Burlingame, Calif., has joined the staff of Stanford Research Institute, Menlo Park, Calif., as a senior scientist attached to the Naval Warfare Research Center. He will participate in problem formulation for projects undertaken by the center and will conduct independent research on specific assignments. The Naval Warfare Research Center was formed in 1957 to provide continuing research on long-range problems of naval operations, with primary emphasis on future naval operations and warfare systems analysis.

KENNETH E. CASTER, paleontologist and professor of geology at the University of Cincinnati, has been invited to become a founding member of the new Brazilian Paleontological Society. Caster is also a member of the Brazilian Academy of Science and a founding member of the Brazilian Geological Society. The latter was organized while Caster was serving as head of the department of geology at the University of São Paulo in 1945.

The Rev. DANIEL LINEHAN, a Jesuit priest and an internationally known seismologist who has just returned from 3 months in Antarctica, has been presented with Fordham University's Insignis Medal. The medal—an award that honors the zeal of Saint Ignatius Loyola, founder of the Jesuit Order—is given to Roman Catholic leaders for extraordinary distinction in the service of God through achievement in their professions. Father Linehan is

head of the geophysics department at Boston College and director of its Weston Seismic Observatory.

JACOB FURTH, associate director of research at the Children's Cancer Research Foundation, Boston, has received the Bertner Foundation Award of the University of Texas M. D. Anderson Hospital and Tumor Institute. Furth was chosen to receive the award for his work in radiation biology. He was the first to demonstrate experimentally the induction of leukemia in mice by the use of whole-body irradiation. He was also the first to demonstrate that ovarian tumors and pituitary tumors could also be induced through the use of whole-body x-rays. Further, he has investigated the effects of radiation upon the endocrine glands and has demonstrated in several organs, including the thyroid and the pituitary, the origin of autonomy in conditioned growth.

WILLIAM G. LYNN, professor of biology at Catholic University of America and specialist in experimental embryology and endocrinology, has been appointed head of the university's department of biology. He succeeds the late Edward G. Reinhard, who died on 29 January.

L. R. HESLER, of the University of Tennessee, dean of the College of Liberal Arts since 1934 and professor of botany since 1919, will retire at the end of the current year. He plans to continue research on southeastern agarics.

The U.S. Naval Research Laboratory has announced the appointment of ALLEN H. SCHOOLEY as the new associate director of research for electronics, succeeding ROBERT M. PAGE, now director of research.

A special award "... in appreciation of his many years of dedicated service" in the field of water pollution abatement was presented recently to RAYMOND W. HESS of Buffalo, N.Y., by the Manufacturing Chemists' Association. Hess is coordinator of pollution research for the National Aniline Division of Allied Chemical & Dye Corporation. He is also an original member and former chairman of the MCA's Water Pollution Abatement Committee.

JOHN E. HEMINGWAY, senior lecturer in geology at the University of Leeds, is visiting lecturer in the department of geology of Northwestern University during the spring term. He is giving a course of lectures on "The Stratigraphy and Sedimentation of the Upper Paleozoic and Mesozoic Rocks of Britain."

SIMON BLACK has been appointed chief of the section on biochemistry and toxicology in the Laboratory of Pharmacology and Toxicology, National Institute of Arthritis and Metabolic Diseases. Black, a chemist with NIAMD since 1954, is replacing O. HAYAISHI, who has accepted a position as chairman and professor, department of medical chemistry, Kyoto University Faculty of Medicine, Kyoto, Japan.

JESSE W. STILLMAN, supervisor of the Physical and Analytical Division of E. I. du Pont de Nemours and Company's Central Research Department, Wilmington, Del., has retired after a career of 41 years with the company during which he pioneered in the application of analytical chemistry to industrial chemical research.

GEORGE E. WAKERLIN has been appointed medical director of the American Heart Association, New York, effective 1 April. He joins the association from the University of Illinois College of Medicine in Chicago, where he has served as professor and head of the department of physiology since 1937. In his new position, Wakerlin will be responsible for planning and directing the medical and scientific programs of the Heart Association. He will fill the post held by the late Eugene B. Ferris.

The University of Washington, Seattle, has announced the appointments of SAUL SCHLUGER, LEO M. SREEBNY, BERTRAM KRAUS, and KENNETH N. MORRISON to the faculty of the School of Dentistry. Schluger is professor of periodontics and director of the graduate dental program. Sreebny is associate professor and executive officer of the department of oral pathology. Kraus is professor of physical anthropology in the department of orthodontics. Morrison is associate professor and executive officer of the department of fixed partial dentures.

RICHARD H. YOUNG, dean of the Northwestern University Medical School, has been named chairman of the American Fund for Psychiatry, Chicago, Ill. He succeeds VERNON W. LIPPARD, dean of the Yale University School of Medicine. The fund provides teaching and research fellowships to young psychiatrists. It is supported by 75 major corporations and several hundred doctors across the country.

A. W. COUTRIS, consulting engineer, has established a firm in his name in Paris. Coutris has been structures and foundation engineer for special projects and problems on the staff of Moran, Proctor, Mueser and Rutledge, New York consulting engineers. He performed analytical studies for a wide variety of projects, including Texas towers, the advance-warning radar stations in the North Atlantic and Puget Sound.

CHARLES K. WEICHERT, head of the department of biological sciences at the University of Cincinnati, has been appointed dean of the university's McMicken College of Arts and Sciences, effective 1 September. He succeeds GEORGE B. BARBOUR, who is resigning the deanship to return to teaching as professor geology.

MORRIS GOODKIND, director and chief bridge engineer of the State Highway Department of New Jersey, has been named the 1958 recipient of the Egleston Medal, Columbia University's highest alumni award for "distinguished engineering achievement." The medal will be presented at ceremonies to be held in the Low Memorial Library as a part of Columbia's annual Engineering Dean's Day program on 19 April.

The 90th birthday of SAMUEL J. HOLMES, professor of zoology emeritus of the University of California at Berkeley, was on 7 March. The staff of the department of zoology honored Holmes at a luncheon at the Faculty Club. Harry B. Torrey, fellow student of Holmes' in the 1890's and former member of the Berkeley faculty, gave an appreciation of Holmes.

Recent Deaths

WILLIAM BENTMAYER, Philadelphia, Pa.; 93; professor emeritus of ophthalmology at the University of Pennsylvania Graduate School of Medicine; 19 Mar.

A. S. BLUMGARTEN, New York, N.Y.; 71; internist and endocrinologist at Lenox Hill Hospital; author of two textbooks for student nurses; contributed many papers to medical journals; 13 Mar.

HAROLD G. COOKE, Abilene, Tex.; 67; president of McMurry College since 1943; 17 Mar.

MERLE C. COULTER, Chicago, Ill.; 63; professor of botany and associate dean in the Division of Biological Sciences at the University of Chicago; author of *The Story of the Plant Kingdom,* a reference work on plant genetics; 18 Mar.

A. E. HOLCH, Denver, Colo.; 66; professor of botany and chairman of the department at the University of Denver since 1931; 12 Mar.

MARLAND KING, Easton, Pa.; 76; professor emeritus of electrical engineering at Lafayette College; 18 Mar.

Book Reviews

Fatigue in Aircraft Structures. Proceedings of the international conference held at Columbia University January 30–February 1, 1956. Alfred M. Freudenthal, Ed. Academic Press, New York, 1956. 456 pp. Illus. $12.

The collection of papers and discussions which constitute this book represent the proceedings of an international conference held at Columbia University early in 1956 under the sponsorship of the Office of Scientific Research, Air Research and Development Command, U.S. Air Force, and the Guggenheim Institute of Flight Structures, Columbia University. The individual contributions have been assembled under three main subject headings: (i) basic physical mechanisms and theories of fatigue; (ii) fatigue testing and methods for predicting fatigue life; and (iii) actual design techniques for the prevention of fatigue failures in aircraft structures.

As a group, the five papers dealing with the basic mechanism of fatigue in metals provide a comprehensive summary of recent experimental and theoretical work in this field. Significantly, most of this work has been carried out in England and Australia. It is also evident that some of the latest theories which have been advanced to account for the origin of fatigue cracks in metals have reached a rather high level of sophistication, incorporating as they do modern concepts regarding the generation, motion, and interactions of dislocations and point defects—that is, vacancies. Although much of the information contained in these papers has been published elsewhere, those who are interested in the basic physical behavior of metals under cyclic stresses will nevertheless find this series of articles instructive.

The next six papers are devoted to the more applied or engineering aspects of the fatigue problem. Among the topics given special treatment here are the mechanics of fatigue crack propagation, the development of testing methods in relation to design needs, the interpretation of fatigue data and statistical prediction of fatigue life, and so on. The remaining eight contributions are concerned primarily with the design procedures which have been developed by the aircraft industry for the prevention of fatigue failures in civilian and military aircraft. These papers are especially interesting since they offer a comparison between the design practices adopted in England, Sweden, France, Australia, and the United States.

To the metallurgist and physicist, as well as the test engineer and aircraft designer who must deal with the effect of metal fatigue on the performance and safety of modern aircraft, this book therefore contains much of interest and value.

LAWRENCE HIMMEL
Metallurgy Branch,
Office of Naval Research

Philosophy of Science. The link between science and philosophy. Philipp Frank. Prentice-Hall, Englewood Cliffs, N.J., 1957. 394 pp. $7.65.

I had intended to say that this book was thirty years out of date, but that would not be quite right. There are references to, and in some cases extended treatments of, contemporary topics scattered throughout the book. It is rather Professor Frank's knowledge of the issues that *concern* philosophers of science and the reasons *why* they concern philosophers of science that is thirty years out of date. Anyone who still thinks that the issue in philosophy of science is between "operational definition" and "metaphysical interpretation" might enjoy reading this book. Afterwards he should learn some *real* philosophy of science.

To take up the issue of operational definition: logicians of science have had considerable difficulty in finding out just what it is that operationalists are contending. Is the operationalist view that talk about molecules is "really" talk about human experiences with measuring apparatus? The only argument for such a view would be that molecules don't "really" exist and that measuring apparatus does "really" exist. This would be itself a metaphysical position (a species of subjective idealism). To make the thesis of operationalism more amenable to scientific discussion it has in general been identified with the *translatability thesis.* The translatability thesis is simply that every sentence in theoretical science is synonymous with some sentence in the observational vocabulary of science—that is, some sentence that does not contain any term purporting to refer to unobservable objects such as "molecules." The translatability thesis is, however, false, as some thirty years of logical investigation have shown. Frank mentions neither the attempts to make the thesis of operationalism precise (for example, Carnap's work on reduction sentences) nor the difficulties that have been shown to arise with the thesis when it is made precise. Rather he says that every term in theoretical science must be "operationally defined" and then proceeds to construe anything and everything as an "operational definition." For instance, he regards the requirement that the forces postulated by physical theory must be expressible as "simple functions" of the distances and velocities as part of the operational meaning of "force," and he says, without blushing, "the Newtonian law of force asserts that there is in every specific case a formula that would be recognized as "simple" by the scientists of our period" (page 111). It is odd to find someone seriously maintaining that Newtonian physics is *about scientists!* More generally, one may reply to Frank as follows: even a realist would admit that a good scientific theory should lead to successful predictions and that it should be as simple as is consonant with success in its predictive and explanatory function. This much can be said for the scientific theory embracing any term or terms whatsoever, not just the term "force." This is a far cry from saying that terms like "force" are *translatable* by means of terms referring to operations, or that when we talk about force, molecules, atoms, and so on, we are "really" talking about scientists or about the operations they perform.

The book might be used as a source book for some fairly standard ("Logical Empiricist") views in philosophy of science. For instance, chapter 3 is a fairly good presentation of the more or less "orthodox" view of geometry, and chapters 13 and 14 represent a surprisingly responsible discussion of current inductive logic. The "orthodox" view of geometry which Frank defends seems to me, however, to be a mistaken one. On this view, pure geometry is regarded as an uninterpreted calculus, and the principle that light travels in straight lines, which is used when we try to derive testable predictions from geometric axioms, is regarded as some sort of operational definition. This seems a distortion of the situation. It would be more accurate to say that even pure geometry is a meaningful theory which, however, does not

have any testable consequences in isolation. It is not unusual for a perfectly meaningful scientific theory to lack testable consequences when considered in isolation. We may say that what we test when we revise or confirm geometrical postulates by reference to physical experiments is not the geometry itself but rather the conjunction of geometry with a certain portion of optics and mechanics. On this account, "light travels in straight lines" is no more a "definition" than the parallels postulate is. It is just a principle of optics, nothing more nor less than that. And if "something goes wrong," we can revise either the geometry or the principles of optics, depending on the nature of the trouble. In certain worlds it might be best to retain Euclidean geometry and say that light does not travel in straight lines. In other worlds it might be best to abandon Euclidean geometry and retain this much of optics. The usual operationalist account hides, where it should emphasize, the fact that optical and geometrical principles figure on a par in scientific inquiry.

Since Professor Frank's book is thirty years out of date (at least in philosophic sophistication), the reader of this review might be interested in knowing where he can find a more contemporary account. Perhaps the best single book on philosophy of science currently available is *Scientific Explanation*, by Braithwaite (Cambridge University Press). For readers with a smattering of symbolic logic there is also a very good monograph by Professor Hempel: "Fundamentals of Concept Formation in Empirical Science" [*International Encyclopedia of Unified Science* (University of Chicago Press), vol. II, No. 7]. Those interested in the issues surrounding operationalism and the so-called verifiability theory of meaning might also read the pioneering articles by Carnap: "Testability and Meaning" and "The Interpretations of Physics" [both of these articles may be found in Feigl and Brodbeck's *Readings in the Philosophy of Science* (Appleton-Century-Crofts), a volume which also contains a large number of other good articles in contemporary philosophy of science]. A critique of Carnap's views by C. G. Hempel was published in a philosophic journal and has been republished in Linsky's *Semantics and the Philosophy of Language* (University of Illinois); a lengthy reply by Carnap, giving his current position, may be found in vol. I of *Minnesota Studies in the Philosophy of Science* (University of Minnesota). Those interested in more general issues in the philosophy of science might read *Philosophy of Science* by Stephen Toulmin (Home University Library)—a book which I do not think is a sound introduction to the philosophy of science, taken by itself, but which supplies some needed corrective to the stark "deductivism" of the Carnap-Hempel-Braithwaite account of scientific theories. And for the detailed examination of specific physical theories there is still no better work available than the writings of the late Hans Reichenbach.

HILARY PUTNAM
*Department of Philosophy,
Princeton University*

An Educational History of the American People. Adolphe E. Meyer. McGraw-Hill, New York, 1957. xx + 444 pp. Plates. $6.

A. E. Meyer states that his new book, *An Educational History of the American People*, is written mainly for novices. The book indeed is a light, interesting history. The author traces his theme from colonial America up to the present. The text has three major divisions: "The Beginnings," describing educational practices in colonial America; "Growth and Evolution," presenting the development of a distinctive public school system; and "Coming of Age," analyzing the emergence of modern educational practice and theory. The last section, which clearly describes the controversies in modern American educational philosophy, is by far the best part of the book.

Undergraduates should enjoy reading this work. Yet a *caveat* must be entered: This is not an impartial history—indeed it is not really a history but, rather, a running commentary. If one looks carefully beneath the intriguing literary style (sometimes Meyer is even too coy in his word usage), one can discover biases and personal judgments. The criticism of public education is a case in point (page 326). Thus, for the more serious layman this story may do more harm than good, for the author's subjectivity often distorts the history of American education.

M. I. BERGER
*New York State College for
Teachers, Albany*

Job Attitudes: Review of Research and Opinion. Frederick Herzberg, Bernard Mausner, Richard O. Peterson, and Dora F. Capwell. Psychological Service of Pittsburgh, Pittsburgh, Pa., 1957. xii + 279 pp. $7.50.

"There is a serious discrepancy between our technological success in creating the machinery for production of goods and services and our understanding and dealings with the people who operate and manage these modern tools of production," asserts the preface to this volume. As the contents make clear, this discrepancy cannot be ascribed to lack of publications; rather, it relates to the restricted quality of the research available.

Research on workers' attitudes has been hampered by a variety of factors. Much of it has been naive or has been motivated by a wish to prove the wisdom of management. Even more has been limited by the difficulty of getting managerial permission to study employees on the job. Problems which should be tackled with a multidisciplinary team and large resources have been studied by one person without even access to high-speed computers. The result is a haystack of bibliographical references in which the wheat is truly hidden by the chaff. Unfortunately, the authors have not been very critical in identifying, for the reader, which items fall into which category.

The book contains a tremendous amount of information which can be valuable to researchers in psychology, medicine, economics, and sociology, as well as to managers and union officers. It should serve an especially useful purpose in spotlighting the gaps in our knowledge of phenomena which might well wreck our technological-economic system if we do not learn to deal more understandingly with them.

ROSS STAGNER
*Department of Psychology,
Wayne State University*

First Symposium on Host Specificity Among Parasites of Vertebrates. Institut de Zoologie, Université de Neuchâtel, Neuchâtel, Switzerland, 1957. 324 pp. Illus.

One of the most outstanding characteristics of parasitism is the specificity for certain kinds of hosts. For a very long time the facts concerning this specificity have been recorded, organized, and filed away with little attempt to analyze the bases upon which it rests, its significance, or its relationship to other biological problems. This symposium records an attempt to pose some of these problems before a group of parasitologists who have concerned themselves with various phases of host specificity and zoologists who are interested in speciation, evolution, phylogeny, and taxonomy of the hosts.

After establishment as a working hypothesis of the existence of some parallelism between the phylogenies of hosts and parasites, the various groups of hosts (mammals, birds, reptiles, and fishes) and of parasites (ectoparasites and helminths) were examined to determine the extent of this parallelism between the

classification of hosts and parasites. As was to have been expected, special emphasis was given to taxonomic groups of hosts whose classification is unclear, in an attempt to determine to what extent information regarding their parasites clarified the classification.

Mammalian phylogeny presents an area in which there is comparatively good agreement. Major problems still exist in the isolated groups such as whales and in the groups now placed in the Edentata. The known data on ectoparasites of these groups are disappointing in their contributions to the solutions of these problems. The more unsatisfactory conditions relative to avian phylogeny offer a more promising opportunity for use of data on parasites (see *Mallophaga of Birds,* by Theresa Clay). Such suggested relationships as that of the Musophagidae to gallinaceous birds and of flamingos to the Anatidae give the students of phylogeny some much needed clues. In the phylogeny of fishes the cestodes are the most reliable indicators of host affinities, but some digenetic trematodes also appear to point the way toward clarification of host phylogeny.

Further generalizations on the subjects treated are difficult. There is much grist here for the phylogenist's mills of the future. It would appear that this first symposium held to seek the degree to which the taxonomists of parasites may lend assistance to the taxonomists of vertebrates and vice versa was successful in pointing the way to future collaboration of the two groups.

C. G. Huff
Naval Medical Research Institute

Advances in Pest Control Research. vol. I. R. L. Metcalf, Ed. Interscience, New York, 1957. vii + 514 pp. Illus. $11.

For the purpose of this book the term *pest* is defined in the preface by the editor as including all organisms that compete with man for his food supply, damage his possessions, and attack his person. This is, no doubt, an intentionally wide definition given with an eye to the future, but the ten articles in this volume are concerned primarily with various aspects of control, by means of chemicals, of arthropods (chiefly insects), fungi, and weeds. Methods of control other than chemical control have not been considered.

The proposed aim of the series is to provide a number of articles by specialists in the various fields of pest control, where the author will not only give a comprehensive review of the particular field but will, in addition, make a critical evaluation of new concepts and developments.

The contribution by J. M. Barnes on the control of health hazards associated with the use of pesticides fulfills this aim admirably. This is also true of the article by A. S. Crafts on the chemistry and mode of action of herbicides, and of the contribution, written in his own inimitable style, by J. G. Horsfall on the mechanisms of fungitoxicity. T. R. Fukuto, in his article on the chemistry and mode of action of organic phosphorus insecticides, has not attempted to give a detailed account of the literature on the chemistry and biological action of this group of chemicals, but is concerned with the more fundamental aspects of the subject. He first describes the enzymes which have been shown to be inhibited by the organophosphorus insecticides and possibly concerned with their toxic action. Then, following an evaluation of the present knowledge of the mechanism of inhibition of esterases by these poisons, the relation between their structure and biological activity and their metabolism by the organism, he derives the molecular characteristics necessary for toxicity, which may also serve as guides in the search for new compounds.

Three contributions deal with the more practical applications of chemicals for pest control. D. B. Kendrick, Jr., and G. A. Zentmyer give an account of the recent advances in the control of soil fungi; G. F. Shambaugh, R. F. Brown, and D. J. Pratt, Jr., give a review of work on repellents for biting arthropods; and W. E. Ripper discusses the status of systemic insecticides in pest control practice. In addition to giving a practical account of the methods of use and the possible uses of systemic insecticides, Ripper considers the theoretical implications of the type of selectivity shown by systemic insecticides and considers its application in the integration of biological and chemical control.

The contribution on the uses of radioisotopes in pesticide research, by P. A. Dahm, summarizes the use of radioactive atoms in insecticides, fungicides, and herbicides. Their use for tagging insects, mites and ticks is also dealt with. The use of radioisotopes in epidemiology and public health and the use of radiation in food preservation and pest control is touched on. Perhaps because the subject is not suitable for theorizing, this article tends to be a catalog of facts. The same comment might be made of the comprehensive review on the chemical analysis of pesticide residues, by M. S. Schechter and I. Hornstein, but here such treatment is necessary if the subject is to be dealt with adequately. These authors have confined their remarks to chemicals used for the control of arthropods, weeds, and fungi but have taken a commendably broad view of techniques, including, for instance, a valuable section on enzymatic methods of analysis.

The other article concerned with the assessment of pesticides, that by Yun Pei Sun on the bioassay of pesticide residues, deals entirely with insecticides. The author deals with the subject as a whole and not particularly with any one aspect of it. A section on the factors influencing results is included. In this section there seems to be the tacit assumption that all the factors influencing the results have been recognized; this would seem to be a rather optimistic view.

The volume of work currently in progress on chemicals for pest control is so great that it is difficult, if not impossible, for any one individual to keep up with progress in all areas of the field by reading original papers. For this reason these authoritative and critical summaries are of the greatest value, and it is to be hoped they will be followed by others equally good.

C. Potter
Rothamsted Experimental Station, Harpenden, Herts, England

The Chemistry of Organic Medicinal Products. G. L. Jenkins, W. H. Hartung, K. E. Hamlin, and J. B. Data. Wiley, New York; Chapman & Hall, London, ed. 4, 1957. x + 569 pp. $10.75.

This new edition of a familiar textbook of organic medicinal chemistry should evoke great interest and enthusiasm among students and teachers alike. While the desirable features of the previous editions have been retained, the reader is impressed by the meticulous care and effort with which each chapter has been revised. It takes cognizance of the newer developments in the ever-changing field of pharmaceuticals by replacing discussion of many obsolete drugs with items of current interest. The text has been rearranged to achieve conciseness by the omission of material which is readily available in other books on general organic chemistry. A new chapter on antibiotics and several flow diagrams showing step-by-step syntheses of many important drugs have been added. Journal references, brought up to date, are quite adequate to arouse interest in readers who would like to pursue the subject matter more deeply. I feel that the chapter on sterioisomerism could be abridged substantially. Inclusion of a general chapter on the chemical changes which drugs undergo during their metabolism and detoxication in the body might not be out of place.

The new format and the change in type have helped to keep the book to a reasonable and handy size. With the added improvements and desirable features, this book should meet more adequately the needs of the student and the instructor.

M. V. Nadkarni
Department of Pharmacology, George Washington University School of Medicine

New Books

Vitamins and Hormones. vol. XV, *Advances in Research and Applications.* Robert S. Harris, G. F. Marrian, Kenneth V. Thimann, Eds. Academic Press, New York, 1957. 366 pp. $9.50.

Naturally Occurring Quinones. R. H. Thomson. Academic Press, New York; Butterworths, London, 1957. 309 pp. $9.

The Naval Architecture of Small Craft. D. Phillips-Birt. Philosophical Library, New York, 1958. 358 pp. $15.

Chemistry of the Steroids. Charles W. Shoppee. Academic Press, New York; Butterworths, London, 1958. 321 pp. $9.

Chronic Radiation Hazards. An experimental study with fast neutrons. G. J. Neary, R. J. Munson, R. H. Mole. Pergamon Press, New York and London, 1957. 201 pp. $7.50.

Advances in Protein Chemistry. vol. XII. C. B. Anfinsen, Jr., Kenneth Bailey, M. L. Anson, John T. Edsall, Eds. Academic Press, New York, 1957. 697 pp. $14.

Process Engineering in the Food Industries. R. J. Clarke. Philosophical Library, New York, 1957. 362 pp. $10.

Symposium on Antibodies: Their Production and Mechanism of Action. Given at Research Conference for Biology and Medicine of the Atomic Energy Commission. Sponsored by the Biology Division, Oak Ridge National Laboratory, Oak Ridge, Tenn., held at Gatlinburg, Tenn., 8–10 Apr. 1957. Oak Ridge National Laboratory, Oak Ridge, Tenn., 1957. 361 pp.

Polyamide Resins. Don E. Floyd. 239 pp. $4.50. *Polyurethanes.* Bernard A. Dombrow. 185 pp. $4.50. *Plastic Sheet Forming.* Robert L. Butzko. 190 pp. $4.50. Reinhold, New York; Chapman & Hall, London, 1958.

Advances in Biological and Medical Physics. vol. V. John H. Lawrence and Cornelius A. Tobias, Eds. Academic Press, New York, 1957. 498 pp. $12.

Transistor Physics and Circuits. Robert L. Riddle and Marlin P. Ristenbatt. Prentice-Hall, Englewood Cliffs, N.J., 1958. 435 pp. $10.

The Harvey Lectures. Delivered under the auspices of the Harvey Society of New York 1956–1957. Under the patronage of the New York Academy of Medicine. Series LII. Academic Press, New York, 1958. 326 pp. $7.50.

The Anatomy of the World. Relations between natural and moral law from Donne to Pope. Michael Macklem. University of Minnesota Press, Minneapolis, 1958. 147 pp. $3.50.

Crystal Structures. Supplement III, Chapters I–VIII. Ralph W. G. Wyckoff. Interscience, New York, 1958. Loose leaf for binder. $20.

Rye-Climate Relationships and the Use of Phenology in Ascertaining the Thermal and Photo-Thermal Requirements of Rye. Based on data of North America and of some thermally analogous areas of North America in the Soviet Union, Finland, Poland, and Czechoslovakia. M. Y. Nuttonson. American Institute of Crop Ecology, Washington, 1958. 224 pp.

The Chemistry of Blood Coagulation. Paul Morawitz. Translated by Robert C. Hartmann and Paul F. Guenther. Thomas, Springfield, Ill., 1958 (originally published as *Die Chemie der Blutgerinnung* by Bergmann, Wiesbaden, Germany, 1905). 194 pp. $4.50.

Advances in Agronomy. vol. IX. A. G. Norman, Ed. Academic Press, New York, 1957. 319 pp. $8.

The Principles of Quantum Mechanics. P. A. M. Dirac. Clarendon Press, Oxford, England, ed. 4, 1958. 324 pp. $5.60.

New Sources of Energy and Economic Development. Solar energy, wind energy, tidal energy, geothermic energy and thermal energy of the seas. Department of Economic and Social Affairs, United Nations, New York, 1957 (order from Columbia University Press, New York 27). 157 pp. Paper, $1.25.

Qualitative Testing and Inorganic Chemistry. Joseph Nordmann. Wiley, New York; Chapman & Hall, London, 1957. 500 pp. $6.25.

The Theory of Groups. Hans J. Zassenhaus. Chelsea, New York, ed. 2, 1958. 275 pp. $6.

Advanced Dynamics. John E. Younger. Ronald Press, New York, 1958. 290 pp. $8.50.

The Changing Population of the United States. Conrad Taeuber and Irene B. Taeuber. Wiley, New York; Chapman & Hall, London, 1958. 368 pp. $7.75.

Economic Applications of Atomic Energy. Power generation and industrial and agricultural uses. Report of the Secretary-General. United Nations, New York, 1957 (order from Columbia University Press, New York 27). 118 pp. $0.50.

Soil Chemical Analysis. M. L. Jackson. Prentice-Hall, Englewood Cliffs, N.J., 1958. 512 pp. $9.

Applied Differential Equations. Murray R. Spiegel. Prentice-Hall, Englewood Cliffs, N.J., 1958. 396 pp. $6.75.

Combination of Observations. W. M. Smart. Cambridge University Press, London, 1958. 267 pp. $6.50.

Therapeutic Heat. Sidney Licht, Ed. Elizabeth Licht, New Haven, 1958. 479 pp. $12.

The Chemistry of the Actinide Elements. Joseph J. Katz and Glenn T. Seaborg. Methuen, London; Wiley, New York, 1957. 523 pp. $14.

Elementary Quantitative Analysis. Harold F. Walton. Prentice-Hall, Englewood Cliffs, N.J., 1958. 351 pp. $5.75.

Laboratory Directions in General Zoology. Mary J. Guthrie and John M. Anderson. Wiley, New York; Chapman & Hall, London, 1958. 241 pp. $3.50.

Miscellaneous Publications

(Inquiries concerning these publications should be addressed, not to Science, but to the publisher or agency sponsoring the publication.)

Science News. No. 45. Archie and Nan Clow, Eds. Penguin Books, Baltimore 11, 1957. 125 pp. $0.65.

Noise from Missile Static Firing and Launch Sites and the Resultant Community Response. WADC Tech. Rept. 57-547. ASTIA Document No. AD 131025. J. N. Cole and H. E. Von Gierke. Wright Air Development Center, Wright-Patterson Air Force Base, Ohio (order from ASTIA Document Service Center, Knott Building, Dayton 2). 45 pp.

Lizard Hunts on the North Coast of Peru. Fieldiana: Anthropology, vol. 36, No. 9. Allan R. Holmberg. 18 pp. $0.75. *The Venomous Coral Snakes of Trinidad.* Fieldiana: Zoology, vol. 39, No. 8. Karl P. Schmidt. 9 pp. $0.25. *Notes on Lizards of the Genus Dicrodon.* Fieldiana: Zoology, vol. 39, No. 9. 8 pp. $0.20. *Geographic Variation in the Central American Colubrine Snake, Ninia Sebae.* Fieldiana: Zoology, vol. 39, No. 10. Karl P. Schmidt and A. Stanley Rand. 12 pp. $0.25. *Birds from Nepal.* Fieldiana: Zoology, vol. 41, No. 1. Austin L. Rand and Robert L. Fleming. 218 pp. $3.50. Chicago Natural History Museum, Chicago, 1957.

The Role of Agriculture in Future Society. Symposium papers, Cornell University, 1957. New York State Agricultural Experiment Station, Geneva, 1957. 69 pp.

The Bromeliaceae of Colombia. Contributions from the U.S. National Herbarium, vol. 33. Lyman B. Smith. Smithsonian Institution, Washington 25, 1957. 311 pp.

Geology of Barro Colorado Island, Canal Zone. Misc. Collections, vol. 135, No. 3. W. P. Woodring. 39 pp. *A New Theory on Columbus's Voyage Through the Bahamas.* Misc. Collection, vol. 135, No. 4. Edwin A. Link and Marion C. Link. 45 pp. Smithsonian Institution, Washington, 1958.

Medical Specialization. A survey of existing legislation. World Health Organization, Geneva, Switzerland, 1958. 39 pp. $0.30.

Malaria Conference for the Eastern Mediterranean and European Regions. Athens, Greece, 11–19 June 1956. WHO Tech. Rept. Ser. No. 132. 47 pp. $0.60. *Expert Committee on Health Statistics, Fifth Report.* WHO Tech. Rept. Ser. No. 133. 22 pp. $0.30. *Joint ILO/WHO Committee on Occupational Health, Third Report.* WHO Tech. Rept. Ser. No. 135. 22 pp. $0.30. *Expert Committee on Yellow Fever Vaccine, First Report.* WHO Tech. Rept. Ser. No. 136. 21 pp. $0.30. World Health Organization, Geneva, Switzerland, 1957. $0.30.

Social Science Research Council, Annual Report. The Council, New York 17, 1958. 90 pp.

Ten Years of Building Research. 120 pp. $1. *National Research Council [Canada], Review, 1957.* National Research Council, Ottawa, Canada, 1957. 289 pp. $0.75.

Reports

Presence, Formation, and Metabolism of Normetanephrine in the Brain

The neurohumoral agent norepinephrine has been shown to be highly localized in the central nervous system (*1*), yet little is known about its metabolism in the brain. Although the role that this catechol amine plays in the action of the central nervous system is still conjectural, knowledge concerning its metabolism may shed some light on its mode of action. In the past, norepinephrine was thought to be transformed by deamination, yet the possibility of there being other pathways has been recognized (*2*). Recent work in this laboratory has shown that the principal pathway for the metabolism of norepinephrine in the rat involves O-methylation to yield normetanephrine (*m*-O-methylnorepinephrine) (*3*) and that this reaction requires S-adenosylmethionine as the methyl donor (*4*). This report describes the presence of normetanephrine in the rat brain as well as the enzymes involved in its formation and metabolism.

Four adult male rats, Osborne-Mendel stock, were given 50 mg of iproniazid phosphate (a monoamine oxidase inhibitor) per kilogram twice daily, intraperitoneally, to block the further metabolism of normetanephrine. After 3 days of treatment with iproniazid, the rats were decapitated, and the brains were removed, chilled, pooled, and immediately homogenized with 1 volume of 0.1*N* HCl. The homogenate was adjusted to *p*H 10.0 with borate buffer and extracted three times with 5 volumes of isoamyl alcohol. After clarification of the isoamyl extract by centrifugation, it was reextracted twice with 0.05 volume of 0.05*N* HCl. The acid extract was evaporated to dryness in vacuum, taken up in methanol, and evaporated to a small volume under nitrogen. The methanol extract was subjected to two-dimensional chromatography (ascending technique) with Whatman No. 1 filter paper; isopropanol:ammonia (5 percent), 8:2, was used as the first solvent system and *n*-butanol : acetic acid : water, 8 : 2 : 2, as the second. After spraying of the chromatogram with 0.1 percent 2,6-dichloroquinone chlorimide in alcohol followed by 0.1*M* *p*H 10.0 borate buffer, a faint but distinct blue spot (R_f's 0.50 and 0.45) appeared. An authentic sample of normetanephrine treated in the same manner had the same R_f's and color reaction (*5*). From the intensity of the blue spot, it was estimated that 0.1 to 0.2 μg of normetanephrine per gram of brain tissue was present. No normetanephrine could be detected in brains of untreated rats (*6*). These observations suggest that rat brain transforms endogenous norepinephrine to normetanephrine and that the latter compound is metabolized further by deamination.

Enzymes in the brain concerned with the above metabolic processes were then studied. Incubation of *l*-norepinephrine *d*-bitartrate with the soluble fraction of rat brain, magnesium chloride, and S-adenosylmethionine resulted in the formation of normetanephrine (Table 1). In the absence of S-adenosylmethionine, or when mitochondria were substituted for the soluble fraction, no O-methylation occurred. Enzymatically formed normetanephrine, isolated and chromatographed as described above, had the same R_f's as a synthetic sample. The rate of O-methylation of norepinephrine in the brain was the same in normal and iproniazid-treated rats.

When normetanephrine was incubated with brain mitochondria, considerable amounts of the amine were metabolized (Table 1). No disappearance of normetanephrine occurred when it was incubated with the soluble fraction. The ability of brain mitochondria, prepared from rats pretreated with the monoamine oxidase inhibitor iproniazid, to metabolize normetanephrine was markedly reduced (Table 1). Further evidence that normetanephrine was deaminated by brain mitochondria was obtained by oxidizing the deaminated product enzymatically to 3-methoxy-4-hydroxymandelic acid. After incubation of normetanephrine, brain mitochondria, aldehyde dehydrogenase (*7*), and diphosphopyridine nucleotide for 2 hours, the reaction mixture was acidified with HCl and extracted with 10 volumes of *n*-butanol. The butanol layer was reextracted with 5 percent sodium bicarbonate solution, and the aqueous layer was reextracted into ethyl acetate at *p*H 1. The ethyl acetate extract was reduced to a small volume under nitrogen and subjected to two-dimensional chromatography as described above. When the chromatogram was sprayed with dichloroquinone chlorimide reagent, the resulting blue spot had the same color and R_f's (0.30 and 0.60) as an authentic sample of 3-methoxy-4-hydroxymandelic acid. Incubating normetanephrine with brain mitochondria and soluble fraction also resulted in the formation of a compound having the same R_f's as 3-methoxy-4-hydroxymandelic acid.

The observations described above indicated the following metabolic pathway for norepinephrine in the brain:

$$\text{Norepinephrine} \xrightarrow[\text{S-adenosylmethionine}]{\text{O-methylation}}$$

$$\text{normetanephrine} \xrightarrow[\text{oxidation}]{\text{deamination}}$$

$$\text{3-methoxy-4-hydroxymandelic acid}$$

At present, conclusive evidence concerning the principal pathway for the

Table 1. Formation and metabolism of normetanephrine in the brain. Intracellular fractions obtained from 100 mg of rat brain were incubated with 0.2 μmole of substrate and 50 μmole of *p*H 7.8 phosphate buffer at 37°C*. After 1 hour of incubation, the reaction mixture was assayed for normetanephrine (*3*).

Cell fraction	Substrate	Additions	Normetanephrine: Formed (μmole)	Normetanephrine: Disappeared (μmole)
Soluble	*l*-Norepinephrine	None	0.00	
Soluble	*l*-Norepinephrine	S-adenosylmethionine	0.02	
Mitochondria	*dl*-Normetanephrine	None		0.10
Mitochondria	*dl*-Normetanephrine	Iproniazid†		0.02

* Magnesium chloride (10 μmole) was added to the incubation mixtures for O-methylation of norepinephrine.
† Iproniazid (200 mg/kgm) was given to rats 1 hour before sacrifice and removal of the brain.

All technical papers are published in this section. Manuscripts should be typed double-spaced and be submitted in duplicate. In length, they should be limited to the equivalent of 1200 words; this includes the space occupied by illustrative or tabular material, references and notes, and the author(s)' name(s) and affiliation(s). Illustrative material should be limited to one table *or* one figure. All explanatory notes, including acknowledgments and authorization for publication, and literature references are to be numbered consecutively, keyed into the text proper, and placed at the end of the article under the heading "References and Notes." For fuller details see "Suggestions to Contributors" in *Science* 125, 16 (4 Jan. 1957).

metabolism of norepinephrine in the central nervous system is lacking. However, from experiments described here and elsewhere (*3*), it appears likely that O-methylation constitutes an important route for the metabolism of the norepinephrine in the brain.

JULIUS AXELROD
National Institute of Mental Health, National Institutes of Health, Bethesda, Maryland

References and Notes

1. M. Vogt, *J. Physiol. (London)* 123, 451 (1954).
2. H. Blaschko, *Experientia* 13, 10 (1957).
3. J. Axelrod *et al., Biochim. et Biophys. Acta*, in press.
4. J. Axelrod, *Science* 126, 400 (1957).
5. Under the conditions described above, metanephrine (*m*-O-methyl epinephrine) has markedly different R_f's from normetanephrine. No metanephrine could be detected in brain extracts of iproniazid-treated animals.
6. Normetanephrine and metanephrine were found to be present in the adrenal glands of iproniazid-treated rats.
7. Purified aldehyde dehydrogenase was prepared by a procedure described by H. Weissbach, B. C. Redfield, and S. Udenfriend (*J. Biol. Chem.*, 229, 953 (1957) and kindly supplied by H. Weissbach.

3 December 1957

Extraction of an Osteogenic Inductor Factor from Bone

The hypothesis that osseous tissue contains an extractable substance which is capable of inducing the formation of new bone has been presented in detail by Bertlesen (*1*), Levander *et al.* (*2*), Willestaedt *et al.* (*3*), and La Croix (*4*) and has been denied by Heinen *et al.* (*5*) and Danis (*6*).

The percentage of all positive experimental results obtained to date, in rabbits and dogs, chiefly by alcoholic or acidic bone extracts (30.8 percent; that is, in 294 of 955 animals reported in the literature), when compared with the percentage of positive results in control animals (22.6 percent; that is, in 74 of 328 animals reported), while statistically significant, leaves room for refinement of techniques (*6*).

Intracerebral implantation (*7*) of a paste of bovine bone (*8*) in the young rat produced endocranial fusion of the normally patent coronal suture after 15 days. This paste had been stored for several months at 4°C in bovine plasma or physiological saline. Histologic examination of all paste samples showed that no living osteocytes or osteoblasts were present. In order to isolate the factors responsible for such osteogenic activity in a relatively resistant host, the following extractive procedures were undertaken.

Either 9 or 18 g of bone paste was incubated for 24 hours at 37°C in a solution consisting of 50 ml of Ringer–Tyrode and 20 ml of distilled water. The mixture was subsequently centrifuged and filtered. The resulting solution was metachromatic to toluidine blue. This reaction was lost after the solution was concentrated on a steam bath to one-fourth of its original volume. The clear brown solution was then stored at 4°C. Storage up to 30 days did not diminish its osteogenic activity.

Pieces of Gelfoam sponge were impregnated with the solution, either before or after concentration, and placed intracerebrally, under parietal bone flaps, in 22 seven-day-old Long-Evans rats. There were ten controls. Fifteen days after intracerebral implantation the animals were sacrificed, and the implantation sites were examined grossly and fixed with 10 percent Formalin. Decalcification with formic acid-sodium citrate solution was followed by paraffin embedding and hematoxylin and eosin staining of 10-μ serial sections.

The results were uniformly positive (Fig. 1). All cases of intracerebral implantation showed extensive osteogenic activity at the site of impregnated Gelfoam exclusively. Osteogenesis was present within the tissues which had invaded the sponge. This inductor activity was shown by all solutions tested, both concentrated and unconcentrated, of either strength, derived from plasma- or saline-stored paste. Grossly, the implants were firm and fused to the host calvaria. They gave a distinctly calcareous impression to a fine steel probe. Histologically, immature trabeculated bone was observed throughout the implant. Some of this new bone was fused to the host endocranial plate. Most of the bone was observed on serial section to have no such continuity. It consisted of isolated islands of osseous tissue in all stages of development. A very strong impression was obtained that these areas of bone had arisen *in situ*. At implantation sites the effective thickness of the calvaria was often four times that of adjacent areas. Active osteogenesis was underway on all surfaces of newly formed bone at sacrifice. The formation of new marrow spaces was frequent. The area of induced osteogenesis never extended beyond the area of implantation. Connective tissue and vascular infiltration and proliferation in the implant area was marked. The sponge had virtually disappeared at this state.

Control animals never showed the slightest osteogenic stimulation or induction following operative procedures alone, or following implantation of either plain, Ringer–Tyrode- or plasma-impregnated Gelfoam.

It seems probable that part of the observed osteogenic response was due to stimulation of preexistent osteoblasts in calvarial implantation sites by some factor extracted from the bone paste. An additional inductive capacity of the extracted solution was also clearly indicated in the numerous sites of new bone formation, demonstrably unconnected with host bone. A spectrum of modulating cell types was noted, ranging from undifferentiated connective tissue cells to mature osteocytes. Intermediate cell types showed increasing basophilia with accompanying cytoplasmic and nuclear enlargement. The intermediate cell type associated with the onset of bone matrix formation possessed an eccentric nucleus, intense basophilia, and a somewhat vacuolated cytoplasm.

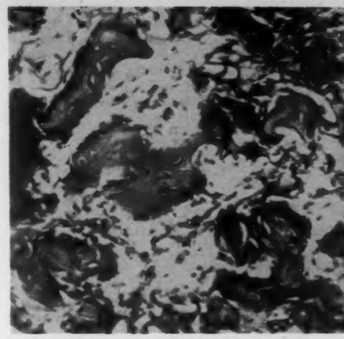


Fig. 1. Island of induced bone, 15 days after intracerebral implantation of Gelfoam impregnated with the extracted solution. Note the typical osteocytes and the sites of continued osteogenesis. This island is unconnected with and well removed from the host bone. In the immediate area several stages of connective tissue metaplasia were observed (× 750).

Biochemical analysis (*9*) of an osteogenically active solution derived from saline-stored bone paste demonstrated a concentration of 0.29 mg/ml of Chondroitin sulfate A or C, or both. This recovered material was redissolved in Ringer–Tyrode in a concentration of 0.1 mg percent. Gelfoam sponges impregnated with this solution were implanted as above and uniformly produced osteogenesis in eight rats. Additional fractions continue to be tested in a variety of heterotopic sites.

MELVIN L. MOSS
Department of Anatomy, Columbia University, College of Physicians and Surgeons, New York

References and Notes

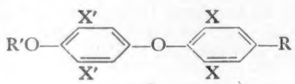
1. A. Bertlesen, *Acta Orthopaed. Scand.* 15, 164 (1944).
2. G. Levander and A. Willstaedt, *Nature* 157, 587 (1946).
3. H. Willstaedt, G. Levander, L. Hult, *Acta Orthopaed. Scand.* 19, 417 (1950).
4. P. La Croix, *The Organization of Bones* (Blakiston, Philadelphia, Pa., 1951).
5. J. H. Heinen, G. H. Dabbs, H. A. Mason, *J. Bone and Joint Surg.* 31A, 765 (1949).
6. A. Danis, *Acta Orthopaed. Belg.* 22, 501 (1956).
7. M. L. Moss, *Anat. Record* 127, 569 (1957).
8. This material was "despeciated calf bone paste" as prepared by E. J. Tucker [*Surg. Gynecol. Obstet.* 96, 739 (1953)]. It was obtained from the Squibb Institute for Medical Research. The present investigation was conducted under a research grant from that institution.

9. This analysis was carried out in the laboratory of Dr. Karl Meyer, Department of Medicine, College of Physicians and Surgeons, Columbia University. The methods have been described by K. Meyer *et al.* [*Biochem. et Biophys. Acta* 21, 506 (1956)] and by P. J. Stoffyn and R. W. Jeanloz [*Arch. Biochem. Biophys.* 52, 373 (1954)].

27 November 1957

Sterically Hindered Analogs of Thyroxine

In previous papers from this laboratory (*1–4*) the synthesis of various compounds of general structure I, related to thyroxine, was reported. In structure I, $R = -CH_2CH_2COOH$, $-CH_2CH(NH_2)COOH$, $-NH_2$, etc; X = iodine; X′ = iodine, methyl, etc.; and R′ = methyl or hydrogen.

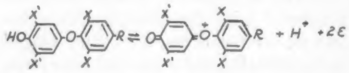


I

In an accompanying paper (*5*), an empirical correlation between structure and biological activity for 47 analogs of structure I was proposed.

The above correlation, while entirely empirical in nature, suggested significant deductions about the essential pharmacogen which is required for thyroxine-like activity. It also led to the conclusions that structural parameters, such as the electron-releasing abilities of X, X′ and OR′, the hydrogen bonding abilities of X and X′ and the *pK* values for the compounds (dependent on the nature of the ionizing side chain, R), are the probable factors which determine the comparative biological activity of these substances. Of major importance to our thinking in arriving at the correlative conclusions was the very striking fact (*5*) that the 3′,5′-dimethyl analogs of L- and D,L- thyroxine (structure I, X = iodine, X′ = methyl, R′ = H) were distinctly more active (*5*), in certain assays of thyroxine-like activity, than the corresponding stereoisomers of thyroxine. The suggestion that substitution of electron-releasing groups, such as methyl, in place of electron-attracting groups such as iodine, bromine, nitro, and so forth, can enhance thyroxine-like activity is a novel one and is in direct opposition to earlier considerations pertaining to such effects (*5, 6*).

The postulate of the Bruice-Kharasch-Winzler correlation, that electron-releasing groups in the 3′,5′-positions of structure I can enhance thyroxine-like activity, finds a possible rationale in the hypothesis of Niemann (*7*) that oxidation of thyroxine to a quinoid form, as shown below, may somehow be involved in its action. Essentially, this oxidation



appears to involve removal of the elements of a hydride group ($H^+ + 2e$) from the thyroxine analog, and this reaction should be enhanced by substituting electron-releasing groups into the back ring of thyroxine.

The above predictions of activities, and the possible relations to the Niemann hypothesis, can be tested by synthesis and biological evaluation of suitable compounds (such as L- and D,L- 3,5,3′-triiodo-5′-methylthyronines and others) in which electron-releasing groups are incorporated into the structures related to compound I. Compare, for example, reference *3*, for the synthesis of initial substances for these purposes.

We now also wish to report our studies toward the synthesis of compounds related to structure I, in which the X′ groups have favorable electron-releasing abilities, but the steric characteristics of which should be such as to cause significant steric complications toward an in vivo oxidative reaction, which may be involved in converting the analog of I to a quinoid form, as illustrated in the equation above. The first compound of this type which we wish to report is the 3′,5′-di-tertiarybutyl analog (X′ = *t*-butyl) and with $R = -CH_2CH_2COOH$. This compound was synthesized by the route shown in Fig. 1.

Compound III melted at 94° to 95°C and gave the following analysis: Calcd. for $C_{25}H_{32}N_2O_8$: C, 61.48; H, 6.56; N, 5.74; found: C, 61.68; H, 6.66; N, 5.57. The conversion of III to I (X = iodine; X′=*t*-butyl; R′=H; $R=-CH_2CH_2COOH$) was carried out by reducing to the diamine, diazotization and use of the Sandmeyer reaction to introduce iodine at the 3,5-positions, and hydrolysis of the intermediate ester; m.p. 120° to 121°C. Analysis (for the ester): Calcd. for $C_{25}H_{32}O_4I_2$: C, 46.16; H, 4.96; I, 39.03; found: C, 46.55; H, 4.97; I, 39.29. The final product, as the free acid, was obtained as excellent colorless needles, from aqueous ethanol, which melted at 197° to 198°C. Analysis: Calcd. for $C_{23}H_{28}O_4I_2$: C, 44.39; H, 4.53; I, 40.79; found: C, 44.53; H, 4.60; I, 40.60.

In the above compound, if the *t*-butyl groups are sufficiently large to block the in vivo oxidative reaction to the quinoid form, and if they are not removable in vivo (a question of general interest, which has yet to be resolved), then the possibility of finding a true competitive inhibitor to thyroxine is implied in this approach. The synthesis of various such molecules (the so-called "hinderins") is therefore a major objective of our studies (*8*).

A sample of "hinderin A" (structure I: X′ = *t*-butyl; X = iodine; R′ = H; $R = -CH_2CH_2COOH$) has been submitted for biological assay (effect on metabolism of glucose in *Aerobacter* aerogenes) by W. Marx and M. Gutenstein, who have reported interesting results for the initial screening.

NORMAN KHARASCH
NARENDRA N. SAHA
Chemistry Department, University of Southern California, Los Angeles

2,6-Di-*t*-butylphenol $\xrightarrow{\text{4 steps}}$ 2,6-di-*t*-butylhydroquinone

2,6-Di-*t*-butylhydroquinone (II) + ethyl β-[3,5-dinitro-4-hydroxyphenyl] propionate ⟶ ethyl β[3,5-dinitro-4-4′hydroxy-(3′,5′-di-*t*-butylphenoxy) phenyl] propionate (III)

Fig. 1. Synthesis of the 3′,5′-di-tertiarybutyl analog of structure I.

References and Notes

1. N. Kharasch, S. I. Kalfayan, J. D. Arterberry, *J. Org. Chem.* 21, 925 (1956).
2. N. Kharasch and S. I. Kalfayand, *ibid.* 21, 921 (1956).
3. T. C. Bruice, R. J. Winzler, N. Kharasch, *J. Biol. Chem.* 210, 1 (1954).
4. T. C. Bruice, N. Kharasch, R. J. Winzler, *J. Org. Chem.* 18, 83 (1953).
5. ——, *Arch. Biochem. Biophys.* 62, 305 (1956).
6. F. Lipmann and C. Dutoit, *Science* 113, 474 (1951); C. Dutoit, *Phosphorus Metabolism* (Johns Hopkins Press, Baltimore, 1952), vol. 2, p. 600.
7. C. Niemann and J. F. Mead, *J. Am. Chem. Soc.* 63, 2685 (1941); C. Niemann and C. E. Redemann, *ibid.* 63, 1549 (1941); C. Niemann, *Fortschr. Chem. org. Naturstoffe* 7, 173 (1950).
8. This work was supported by the U.S. Public Health Service (grant No. A-703 (C3) and by the Travenol Laboratories of Morton Grove, Ill.

10 October 1957

On the Composition of Zymosan

Zymosan is the name given by Pillemer and Ecker (*1*) to a yeast fraction having the specific immunological property of inactivating the third component of complement, C′3. Later work indicated that zymosan adsorbs properdin, a radiation-sensitive serum protein reported to protect mammals from the spread of microbiological infection (*2*). Further interest in zymosan is derived from the finding that its injection into mice, rats, and rabbits results in an immediate decrease in the properdin titer followed by an increase to levels sometimes three times greater than the initial properdin level (*3*). Consistent with this property are the observations that zymosan decreases the lethal effect of x-radia-

tion (4) and increases the bactericidal activity of animal sera (5).

Zymosan preparations defined as types A and B on the basis of immunological tests were isolated from Fleischmann yeast by the procedure published by Pillemer *et al.* (6). Table 1 contains analytical data developed on three preparations of zymosan type A and on one sample of zymosan type B. The analytical differences between the two types of zymosan are no greater than the variations noted among different preparations of zymosan type A. Therefore, the difference in immunological activity of zymosan types A and B cannot be ascribed to gross chemical composition. One possibility is that surface structure and charges determine zymosan activity. Following is a brief description of the analytical procedures employed in this work.

Table 1. Composition of zymosan.

Component	Percentage by weight, dry basis			
	Type A			Type B
	7B13	7B152	7B340	6B506
Total polysaccharide	75.7	70.7	73.0	74.7
Glucan	57.8	53.8	50.7	56.7
Mannan	17.9	16.9	22.3	18.0
Total nitrogen	2.32	2.79	2.19	2.27
Protein nitrogen	2.26	2.73	2.13	2.20
Glucosamine nitrogen	0.06	0.06	0.06	0.07
Protein	14.1	17.1	13.3	13.8
Glucosamine	0.71	0.75	0.74	0.87
Chitin*	0.78	0.83	0.82	0.95
Fat	6.4	6.9	6.9	5.5
Ash	3.42	2.98	3.42	2.94
Phosphorus	0.79	0.77	0.79	0.71
Magnesium	0.28	0.28	0.28	0.51

* Calculated from the glucosamine analysis.

A zymosan sample (about 200 mg, accurately weighed) was hydrolyzed by shaking at 30°C with 10 ml of 22*N* sulfuric acid solution for 16 hours. The mixture was diluted with 40 ml of water and boiled under reflux for 1 hour. An insoluble material separated on cooling and was removed by filtration through sintered glass. The residue was washed thoroughly with water. The combined washings and filtrate were brought to *p*H 8 with 10*N* sodium hydroxide solution. The solution was concentrated by distillation under high vacuum and brought to a volume of 50 ml. [A total carbohydrate analysis performed with anthrone (7) showed that all of the polysaccharide present in zymosan was solubilized.] Aliquots were submitted to paper chromatography on 5½- by 17-inch sheets of Whatman No. 1 paper; the developing solvent was N-butyl alcohol, absolute ethyl alcohol, and water [2:1:1]. The multiple development technique (8) was employed over a period of 7 days—that is, the chromatograms were removed daily, dried, and returned to the developing tanks during the seven days that the chromatography was performed. Finally, the chromatograms were treated by conventional techniques for the identification of monosaccharides. Only glucose and mannose were present; analyses were conducted on eluates by the anthrone procedure (7).

Glucosamine analyses were conducted on the same sulfuric acid digest as that used for glucose and mannose assays. The modified method (9) of Elson and Morgan (10) was employed. Glucosamine was identified by previous work with zymosan hydrolyzates produced in sealed tube reactions with 2*N* hydrochloric acid at 100°C (11); this type of hydrolyzate was not used for quantitative work because carbohydrates other than simple sugars were present on the paper chromatograms. The identification of glucosamine in such hydrolyzates was based upon (i) the correspondence of its R_G with the value obtained from work with pure glucosamine, (ii) the positive response of the material to staining with aniline phthalate and with ninhydrin, (iii) the finding that the eluate produced a red solution with maximum absorption at 530 mμ on treatment with acetylacetone and *p*-dimethylaminobenzaldehyde (12), and (iv) the failure of the eluate to produce color with anthrone (7). A positive qualitative test for chitin was obtained by hydrolyzing zymosan with alkali in a sealed tube and producing a red-violet color by treating the resulting chitosan with potassium iodide–iodine solution (13). Zymosan samples were assayed for ash by dry combustion at 550°C to constant weight. Procedures described in the literature were used to determine fat (14), phosphorus (15), and magnesium (16). The ultraviolet absorption spectrum of zymosan hydrolyzates did not reveal the presence of nucleic acid split-products (17). On the average, the analytical values presented in Table 1 account for 98.6 percent of the material as 54.7 percent glucan, 18.8 percent mannan, 14.5 percent protein, 6.6 percent fat, 3.2 percent inorganic material, and 0.8 percent chitin. Zymosan contains both the yeast cell wall polysaccharides described by Northcote and Horne (11)—namely, the outer glucan shell and the inner mannan layer. It is interesting to note the ratio of mannan to glucan in the following materials: 1.6 for whole yeast (18); 1.0 for "cell-wall" (11), and 0.34 for zymosan (Table 1).

Recently, Falcone and Nickerson (19) prepared and analyzed yeast cell wall substance; their material, like zymosan, contains no nucleic acid. Zymosan contains twice as much nitrogen (2.36 percent) as yeast "cell wall" isolated by Falcone and Nickerson, and somewhat more nitrogen than the yeast "cell wall" preparation of Northcote and Horne (2.1 percent nitrogen).

Photomicrography confirms the statement that zymosan is derived from the yeast cell wall (1). Photomicrographs of Gram-stained zymosan and yeast show that zymosan consists of "ghost" cells. The average particle diameter of zymosan is about 3 μ; yeast cells have an average diameter of approximately 6 μ (20).

FREDERICK J. DI CARLO
JOSEPH V. FIORE
Fleischmann Laboratories, Standard Brands, Inc., Stamford, Connecticut

References and Notes

1. L. Pillemer and E. E. Ecker, *J. Biol. Chem.* 137, 139 (1941).
2. L. Pillemer *et al., Science* 120, 279 (1954).
3. L. Pillemer and O. A. Ross, *ibid.* 121, 732 (1955).
4. O. A. Ross *et al., Federation Proc.* 14, 418 (1955).
5. B. Blattberg, *Proc. Soc. Exptl. Biol. Med.* 92, 745 (1956).
6. L. Pillemer *et al., J. Exptl. Med.* 103, 113 (1956).
7. L. H. Koehler, *Anal. Chem.* 24, 1576 (1952).
8. A. Jeanes, C. S. Wise, R. J. Dimler, *ibid.* 23, 415 (1951).
9. J. W. Palmer, E. M. Smythe, K. Meyer, *J. Biol. Chem.* 119, 491 (1937).
10. L. A. Elson and W. T. J. Morgan, *Biochem. J.* 27, 1824 (1933).
11. D. H. Northcote and R. W. Horne, *ibid.* 51, 232 (1952).
12. N. F. Boas, *J. Biol. Chem.* 204, 553 (1953).
13. P. A. Roelofsen and I. Hoette, *Antonie van Leeuwenhoek J. Microbiol. Serol.* 17, 297 (1951).
14. Assoc. Official Agr. Chemists, *Official Methods of Analysis*, ed. 6 (1945), p. 240.
15. R. E. Kitson and M. G. Mellon, *Ind. Eng. Chem. Anal. Ed.* 16, 379 (1944).
16. H. A. J. Pieters, W. J. Hanssen, J. J. Geurts, *Anal. Chim. Acta* 2, 241 (1948).
17. F. J. Di Carlo and A. S. Schultz, *Arch. Biochem.* 17, 293 (1948).
18. C. W. Chung and W. J. Nickerson, *J. Biol. Chem.* 208, 395 (1954).
19. G. Falcone and W. J. Nickerson, *Science* 124, 272 (1956).
20. We are indebted to the late Prof. Louis Pillemer, Department of Pathology, Western Reserve University, Cleveland, Ohio, not only for immunological work but for stimulating discussion. We are grateful also for technical assistance given by Mr. Herbert J. Kothe, Mr. John A. Lally, Mr. Lawrence Kogan, and Miss Isabel Steinfeld of Fleischmann Laboratories.

15 November 1957

N,N-Dimethyl-p-phenylenediamine Oxidation by Serum from Schizophrenic Children

Interest in the oxidation of aromatic amines has been renewed by the work of Akerfeldt (*1, 2*) with the in vitro oxidation of N,N-dimethyl-*p*-phenylenediamine dihydrochloride (DPP) by the serum of normal and schizophrenic patients. Since a survey of the literature failed to reveal any published data concerning this oxidation reaction in the case of children, we have examined the sera from 23 children hospitalized because of psychiatric illness. The group ranged in age from 6 to 13 years. There were 5 female and 18 male children.

The Akerfeldt test (*1*) was modified slightly to yield a final solution of serum and DPP whose *p*H was between 7.00 and 7.15 (*3*). Three parameters were used in the analysis of the biochemical data. The first was the value of the slope when the optical density at 552 mμ was plotted against time. The second was the length of lag period which resulted in the majority of cases prior to the oxidation of DPP. The optical density at 552 mμ, determined 5 minutes after the addition of DPP to the serum, served as the final parameter. The length of the lag period has been shown to be a function of the amount of ascorbic acid in the serum (*1, 3*). The rate of change of optical density is the result of the influence of ceruloplasmin and the apposing activity of sulfhydryl groups (*2*) as well as other metabolites (*4*).

Observations in ten cases in which the psychiatric diagnosis (*5*) was not schizophrenia (group A) are given in Table 1. Seven cases specifically designated as schizophrenia (group B) by the attending psychiatrist, as well as an additional group of six cases in which the diagnosis of schizophrenic reaction is likely but not satisfactorily documented beyond reasonable doubt (group C), are also presented.

The biochemical criteria used to determine an abnormal response were as follows: (i) a lag period in the 0- to-1.6-minute range *and* (ii) an optical density reading of 0.39 or higher at 552 mμ after 5 minutes. Both criteria had to be met; if only one was satisfied the test was considered to be borderline.

The lag periods and optical density readings of the sera from the children in group A indicate that eight were "biochemically normal," one (No. 22) was borderline, and one (No. 21) showed an abnormal response. On the basis of these biochemical measurements, child No. 21 was thought to be schizophrenic; this interpretation was not in agreement with the psychiatric diagnosis. In the remaining nine subjects the absence of an abnormal response bore out the psychiatric diagnosis.

Of the children in group B, only in cases 5 and 14 did the results permit a prediction of schizophrenia on the basis of the biochemical data. In group C, only cases 11 and 15 met both biochemical criteria for such a prediction. The results in the cases of the remaining children in groups B and C were typical of those obtained from normal adults.

Statistical analysis of the data in groups A, B, and C failed to reveal any significant differences between the values for optical density, slope, or lag period obtained from biochemical measurement of the sera of schizophrenic children and those obtained from measurement of the sera of nonschizophrenic children. These results, therefore, offer little or no support for the suggestion that the Akerfeldt-type reaction can be used to distinguish between schizophrenic and nonschizophrenic children. Similarly, Horwitt *et al.* (*6*) were unable to distinguish, on the basis of the Akerfeldt test, between normal and schizophrenic adults.

M. H. Aprison
A. L. Drew
Institute of Psychiatric Research, Indiana University Medical Center, Indianapolis

Table 1. Biochemical parameters and psychiatric diagnosis of 23 children hospitalized because of psychiatric illness.

Case No.	Biochemical parameters: Slope	Lag period (min)	Optical density (552 mμ) at 5 minutes	Psychiatric diagnosis
		Group A		
12	0.168	3.2	0.32	Passive-aggressive
22	0.162	1.8	0.48	Chronic brain syndrome
6	0.132	3.4	0.22	Anorexia nervosa
7	0.126	4.1	0.17	Passive-aggressive
21	0.120	0.0	0.56	Passive-aggressive
1	0.120	4.0	0.17	Psychoneurosis
20	0.120	4.2	0.13	Mental retardation
17	0.120	2.3	0.32	Maladjustment, childhood
2	0.108	6.0	0.02	Emotional instability
4	0.108	3.8	0.16	Psychoneurosis
		Group B		
5	0.300	< 0.5	0.80*	Schizophrenia, autism
18	0.138	3.2	0.30	Childhood schizophrenia
8	0.138	5.5	0.03	Childhood schizophrenia
14	0.120	0.0	0.45	Childhood schizophrenia
9	0.120	4.3	0.13	Childhood schizophrenia
3	0.114	4.1	0.12	Schizophrenic reaction
13	0.084	3.8	0.13	Schizophrenic reaction
		Group C		
15	0.138	< 0.4	0.60	Schizoid personality
10	0.138	3.4	0.25	Childhood schizophrenia
11	0.170	< 0.4	0.39	Childhood schizophrenia
19	0.120	4.0	0.15	Schizophrenia (questioned)
23	0.114	5.0	0.03	Schizophrenia (questioned)
16	0.090	3.7	0.11	Schizophrenic reaction

* At 3.8 minutes.

References and Notes

1. S. Akerfeldt, *Science* 125, 117 (1957).
2. ———, work reported at the meeting of Brain Research Foundation, Chicago, Ill. 12 Jan. 1957.
3. M. H. Aprison and H. J. Grosz, *A.M.A. Arch. Neurol. and Psychiat.*, in press.
4. M. H. Aprison *et al.*, unpublished data.
5. We acknowledge the psychiatric assistance of Dr. J. H. Wells.
6. M. K. Horwitt *et al.*, *A.M.A. Arch. Neurol. Psychiat.* 78, 275 (1957).

18 November 1957

Absorption of C[14]-Labeled Sucrose by Alfalfa Nectaries

The physiological significance of nectar in the life of the plant has not been adequately determined. Bonnier, in 1878 (*1*), observed that reabsorption of nectar took place if it were not removed from the flower before pollination. Pankratova reviewed this subject in 1950 (*2*).

In the studies reported here, C^{14}-labeled sucrose was used to demonstrate the reabsorption of nectar and its distribution in the plant. A special capillary pipette was used to place 0.001 ml of a 40-percent solution of C^{14}-labeled sucrose on the nectary of an alfalfa flower. All

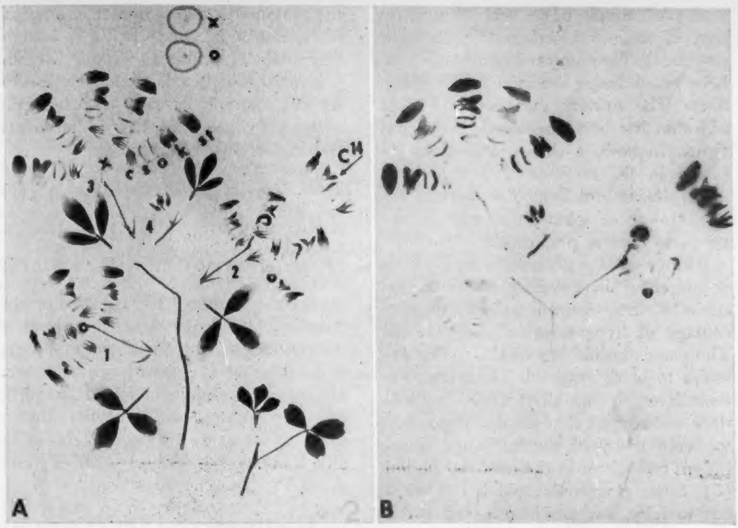


Fig. 1. Results of the experiments described in text, shown in photograph (*A*) and in autoradiogram (*B*). The point of application is indicated by the arrow. The flower parts are arranged from the outside in the following order: standard petal (*st*), wings and keel (*k*), ovary (*o*), staminal column (*s*), and calyx (*c*). On the raceme (2) with the treated flower, the pods from three of the flowers in addition to that from the treated one became radioactive, but the floral parts which had developed before the treatment did not react. One pod failed to grow. All parts of the five flowers of the upper raceme (3) which opened after the treatment became radioactive. Nectar from this raceme (3) and from the one below (1) was placed in the circles labeled *x* and *o* at the top of *A*. This nectar was also radioactive. The raceme at the lower left (1), which was in full bloom at the time of treatment, was not pollinated and became only partially radioactive. The terminal bud (4) located approximately in the center of *A* and the leaf at the lower right that developed after treatment were radioactive. Older leaves that had completed growth before treatment did not create an image on the negative. [Photographic work by W. P. Nye]

flowers on the raceme, including the treated one, were cross-pollinated by hand just before treatment. The plants were grown in a greenhouse in the absence of pollinating insects. After 6 days the plant was dissected, mounted on cardboard, pressed, and dried, and autoradiograms were prepared.

The results of the experiments, as shown by the autoradiogram (Fig. 1B) and picture (Fig. 1A), demonstrate that nectar is reabsorbed. The absorbed material is distributed primarily to growing parts of the plant, such as leaves, flowers, and pollen, but can also be found in the roots and in nectar of flowers that develop after the treatment.

Leaves which were completely developed before treatment did not become radioactive. On an adjacent raceme, flowers that had opened before treatment were much less radioactive than those that opened after treatment. However, nectar from flowers on both racemes showed images on the autoradiogram. In this case, nectar (as sucrose with C^{14}) was absorbed from a flower on one part of the plant and translocated and secreted in flowers some distance away (see Fig. 1). Similar results have been obtained with a number of other species.

In a time series test, parts of alfalfa plants adjacent to treated flowers were removed and checked for radioactivity at intervals of ½, 1, 3½, and 8 hours after treatment. These showed that reabsorption occurred within ½ hour after treatment and pollination, and that the amount of reabsorption was roughly proportional to the time interval after treatment.

On the assumption that sucrose is representative of nectar, it has been demonstrated that nectar is absorbed by nectaries as well as secreted by them. The fact that absorption occurred shortly after treatment suggests that nectar is not a static product (dissociated, so to speak, from the plant) but is in close contact with the plant system. Additional work will be needed to show whether or not nectar is also absorbed prior to pollination or senescence of the flower.

The question arises as to whether or not the nectar that is not removed by bees has any significance in the production of seed. If it does, the good production of alfalfa seed obtained by use of bees which collect mainly pollen may be partly a result of the fact that less nectar is collected. Obviously, nectar is a source of food adjacent to the developing embryos in a fertilized flower. Brink and Cooper (*3*) considered the nutrient supply to the seed to be a factor in seed failure.

M. W. PEDERSEN
CECIL W. LEFEVRE
Agricultural Research Service, U.S. Department of Agriculture, Logan, Utah
H. H. WIEBE
Department of Botany and Utah Agricultural Experiment Station, Utah State University, Logan

References

1. G. Bonnier, *Ann. Sci. Nat. Botan. et biol. végétale* 8, 212 (1878).
2. N. M. Pankratova, *Zhur. Obshchei Biol.* 11, 292 (1950).
3. R. A. Brink and D. C. Cooper, *Botan. Rev.* 13, 423 (1947).

16 December 1957

Conversion of Indirect- to Direct-Reacting Bilirubin in vivo

It is now well established that the difference between indirect- and direct-reacting bilirubin lies in the fact that the latter is conjugated with glucuronic acid (*1*). Considerable evidence indicates that indirect bilirubin in high concentrations is toxic to the nervous system (*2*), particularly in the neonatal period. Kernicterus, which is found in association with high levels of indirect bilirubin in the plasma, is regarded as bilirubin encephalopathy. If it were possible to control the high levels of indirect bilirubin in hemolytic disease of the newborn and in other hyperbilirubinemias seen at this time of life, the need for exchange transfusions would no longer exist.

It is known that an enzyme, glucuronyl transferase, involving uridine diphosphate glucuronic acid is concerned in the esterification of bilirubin with glucuronic acid (*3*), an enzyme which is deficient in the liver of the newborn (*4*). In addition, there appears to be an extrahepatic mechanism for the conversion of bilirubin to its glucuronide, although the

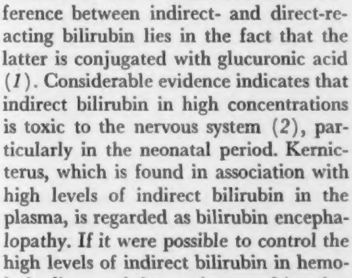


Fig. 1. A hyperbilirubinemic infant showed a 17-mg drop in indirect bilirubin during oral administration of 15 g of glucuronic acid.

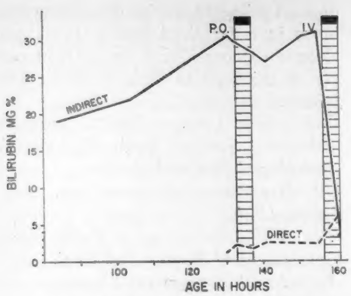


Fig. 2. A hyperbilirubinemic premature infant showed a negligible response to the oral administration of 5 g of glucuronic acid but a large decrease in indirect bilirubin during intravenous administration. Note the slight rise in the direct-reacting pigment during intravenous administration.

details of the reaction are not known at present (5). Even though there are no known pathways for the utilization of free glucuronic acid in glucuronide syntheses, there is some experimental evidence that such a pathway may exist. Attempts have been made to promote glucuronide conjugation in man (6) and animals (7) with glucuronic acid or glucuronolactone, but the results of these investigations are contradictory and inconsistent. Nevertheless, it seemed desirable to make the attempt to control indirect hyperbilirubinemia in the newborn by the administration of glucoronic acid.

This attempt has met with a considerable measure of success. Twenty-eight infants with hyperbilirubinemia have been treated to date by oral administration of glucuronic acid. In 16 of these a striking fall in the concentration of indirect bilirubin was observed, as is illustrated in the accompanying graph (Fig. 1), with an equally striking rebound within a few hours after the discontinuance of the conjugating agent. A simultaneous but less marked rise in direct bilirubin has been observed in some, but not in all instances. Of the 16 patients who responded, 10 were infants with erythroblastosis, the remainder being instances of physiological hyperbilirubinemia in which the concentration of indirect bilirubin exceeded 20 mg/100 ml. Of the patients who failed to respond to the oral administration of glucuronic acid, one, a premature infant, subsequently responded to intravenous administration of the acid (Fig. 2). Administration of glucuronic acid by the oral route produced a mild-to-moderate amount of watery diarrhea and acidosis in most of the infants treated. This prompted us to pursue intravenous glucuronic acid therapy further. We have now treated 14 additional infants by intravenous administration of glucuronic acid (and simultaneous oral administration of sodium bicarbonate); 12 have responded. No untoward symptoms have been noted during the injection or thereafter. The urinary excretion of direct bilirubin has been measured in two patients. In both, a three- to fivefold increase in the conjugated product was noted during and immediately after administration of glucuronic acid as opposed to control periods.

It appears that glucuronic acid per se is successful in lowering indirect bilirubin levels in serum in a significant percentage of hyperbilirubinemic patients. The exact mechanism of this action remains to be determined. These observations have obvious therapeutic implications and suggest that it may be possible to avoid many of the exchange transfusions now given in the neonatal period (8). Since glucuronic acid is not without toxicity, caution is required in its clinical use.

STUART DANOFF, CHARLOTTE GRANTZ
AUDREY BOYER, L. EMMETT HOLT, JR.
Department of Pediatrics, New York University College of Medicine, New York

References and Notes

1. R. Schmid, *Science* 124, 76 (1956); B. H. Billing and G. H. Lathe, *Biochem, J.* 63, 6 (1956); E. Talafant, *Nature* 178, 312 (1956).
2. R. L. Day, *Proc. Soc. Exptl. Biol. Med.* 85, 261 (1954); W. J. Waters and W. R. Bowen, *Am. J. Diseases Children* 90, 603 (1955).
3. J. V. Carbone and G. M. Grodsky, *Proc. Soc. Exptl. Biol. Med.* 94, 461 (1957); ———, *J. Biol. Chem.* 226, 449 (1957); R. Schmid, L. Hammaker, J. Axelrod, *Arch. Biochem. Biophys.* 70, 285 (1957).
4. A. Brown, *A.M.A. J. Diseases Children* 94, 510 (1957); P. S. Lacson and W. J. Waters, *ibid.* 94, 510 (1957); G. H. Lathe and M. Walker, *Biochem J.* 67, 9 (1957).
5. H. H. Weinbren and B. H. Billing, cited by B. H. Billing and G. H. Lathe, *Am. J. Med.* 24, 111 (1958); J. L. Bollman and F. C. Mann, *Arch. Surg.* 24, 675 (1932); J. L. Bollman, *Proc. 5th Pan-American Congr. Gastroenterol.* (1956).
6. F. Eisenberg, J. B. Field, D. Stetten, *Arch. Biochem. Biophys.* 59, 297 (1955).
7. J. F. Douglas and C. G. King, *J. Biol. Chem.* 198, 187 (1952).
8. A paper describing the details of these observations is in preparation.

26 November 1957

A Theory of Active State Mechanisms in Isometric Muscular Contraction

This report (1) presents in outline a formulation of the interaction of the contractile component and the series elastic component of isometrically contracting muscle. In general our theory is like that of Hill (2), but our assumptions and other details are significantly different. Our first assumption is that the basic property of the active state of the contractile component, the capacity to bear a load [given maximally by P_0 (g), the maximal force in isometric tetanus], is dependent on time (Hill's P_0 was independent of time). In simple, first approximation it is assumed that after onset this parameter rises exponentially with time constant α_1 (sec). Thus Hill's classic force-velocity relation,

$$(P+a)(v+b)=b(P_0+a), \quad (1)$$

is altered to read

$$(P+a)(v+b)=b[P_0(1-e^{-t/\alpha_1})+a]. \quad (2)$$

In these equations: P(g) = force of the muscle; v(cm/sec) = shortening speed of the contractile component; t(sec) = time; and a(g) and b(cm/sec) are constants. We normalize Eq. 2, and all subsequent ones, so that quantities having dimensions of force are measured relative to $P_0=1$. Thus, by defining $p=P/P_0$ and $a_0=a/P_0$, Eq. 2 becomes

$$(p+a_0)(v+b)=b(1-e^{-t/\alpha_1}+a_0). \quad (2a)$$

Our second assumption is based on the now well-known (3–6) nonlinear elasticity of the series elastic component [Hill (2) assumed a linear elasticity], and we express this by

$$p=f(e^{s/\lambda}-1), \quad (3)$$

in which s(cm) = the strain; p = the normalized stress; and f and λ (cm) are constants. By proper choice of f and λ, this equation can be made to fit the data of each of the previously mentioned studies (3–6) with remarkable accuracy.

Now, by differentiation of Eq. 3, the velocity of strain of the series elastic structure in an isometric contraction is

$$v=\frac{ds}{dt}=\frac{\lambda}{p+f}\frac{dp}{dt}, \quad (4)$$

which, on substitution in Eq. 2a, yields

$$\frac{dp}{dt}=\frac{b}{\lambda}\left(\frac{p+f}{p+a_0}\right)(1-e^{-t/\alpha_1}-p). \quad (5)$$

This equation cannot be explicitly integrated and must therefore be solved numerically. However, this is required over only a very short initial time interval, for, as will be seen later, α_1 is very small compared with the total contraction period of a tetanus (or even of a twitch), and so for times greater than about $5\alpha_1$, Eq. 5 reduces to

$$\frac{dp}{dt}=\frac{b}{\lambda}\left(\frac{p+f}{p+a_0}\right)(1-p), \quad (6)$$

for which the explicit integral is

$$\frac{2bt}{\lambda}=\ln\frac{f}{(f+p)(1-p)}+\frac{2a_0+1-f}{1+f}\ln\frac{f+p}{f(1-p)}. \quad (7)$$

For computation of Eqs. 5, 6, and 7 we use, for the frog sartorius, here studied at 20°C, the standard average values:

$a_0 = 0.25$, $b = 4.0$ cm/sec, and P_0 as will be involved later for particular muscles. Unfortunately, corresponding appropriate values for f and λ are not available even though, as previously mentioned, they can be calculated from other work: but they vary too greatly, they correspond to muscles of other species than ours (*Rana pipiens*), and, in some cases, certain data (P_0, weight, and length) of the muscles, needed for critical evaluation of the stress-strain data, are not given. We therefore obtain these constants from our theory and experimental tetanus myograms as follows. By using analytical procedures on Eq. 6, we determine the equation corresponding to dp/dt at maximum and put it into the form

$$f = \frac{a_0(1-2p_m) - p_m^2}{a_0+1}, \qquad (8)$$

in which p_m is the value of p for $(dp/dt)_{max}$. (Eq. 6 is usable here, and not necessarily Eq. 5, since for p_m, $t > 5\alpha_1$.) Since a_0 is known, and since p_m can be determined from an experimental record as given in Fig. 1 (here, 0.280), f can be computed = 0.0256. Equation 6 is now used to calculate λ, by inserting in it the known constants and matched values of p and dp/dt obtained from the records of Fig. 1. With p varying from 0.1 to 0.74, five such determinations give an average $\lambda = 0.0537 \pm 0.0035$ (S.E.) cm. By way of comparison, our values for f and λ agree fairly well with those, 0.0353 and 0.0476 cm, required, respectively, to make Eq. 3 fit Wilkie's (*6*) data (if it be assumed his $P_0 = 60$ g). Furthermore, using our constants in Eq. 3 and setting $p = 1$, we obtain s_m, (the maximum strain present in the series elastic component at tetanus plateau) = 0.188 cm—that is, 6.3 percent of the rest length (3.0 cm) of our muscle. For the toad sartorius, Hill (*4*) determined that s_m is 3 to 4 percent of muscle length. Our larger value may be due to a species difference.

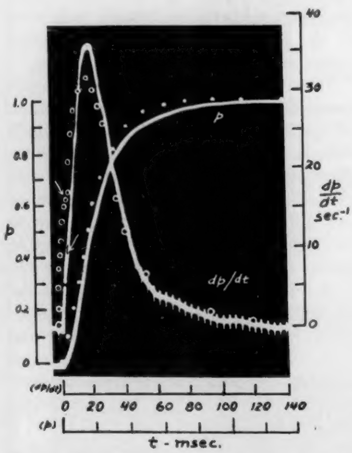


Fig. 1. Dual beam cathode-ray oscillographic records (*8*) of tension development (p) and its derivative (dp/dt) in maximal isometric tetanus contraction of a massively stimulated, curarized frog sartorius muscle (rest length, 3.0 cm; weight, 67 mg; and P_0, 48.3 g) at 20°C. Tension was registered by the RCA Type 5734 mechano-electronic transducer tube. Time is measured from onset of contraction. The time constant of the electronic differentiating circuit is 0.1 msec. (Timing corrections must be made for the direct contraction trace due to imperfect synchrony of its sweep with that of the derivative and because of relative tilt of the vertical axis of that trace.) Corresponding myograms calculated by the theory are represented by the dots for p and the circles for dp/dt. The arrows mark the active state "hump."

Since all the constants of Eqs. 5 and 7 are now known, theoretical $p(t)$ curves can be computed. Comparisons will be made with the experimental equivalents (of one frog sartorius muscle) shown in Fig. 1 which have already been used to determine the elasticity constants. Presentation of more extensive results indicating variability is not necessary here since they provide nothing different in principle. The theoretical myogram of Fig. 1 has been computed over the range from 0 to 0.01 sec by an approximate integration of Eq. 5 with $\alpha_1 = 0.001$ sec, and from then on by means of Eq. 7. The theoretical points do not perfectly match the experimental ones, but the general fit is quite good and the theoretical curve especially includes the sigmoid foot [absent in Hill's curves (*2*)] so characteristic of actual myograms.

Figure 1 also presents dp/dt curves, the theoretical determined by means of Eqs. 5 and 6. In general there is good agreement between theory and experiment, as would be expected from the $p(t)$ curves. But of special interest is the little "hump" that appears very early in these myograms (see also Fig. 2). Theoretical considerations prove that the hump, even though it appears too high up on the theoretical curve, marks the termination of development of the active state and that this should occur at about 4.5 msec after onset of contraction, as it does in experimental records. These results are of the greatest interest, for they (i) involve a first observation of a feature of the early phase of contraction which, (ii), according to the theory, marks the instant at which the active state has developed to full intensity, and (iii) they provide verification of our assumption that after onset the active state develops exponentially with time constant α_1.

The preceding deals only with the tetanus contraction period—a relatively

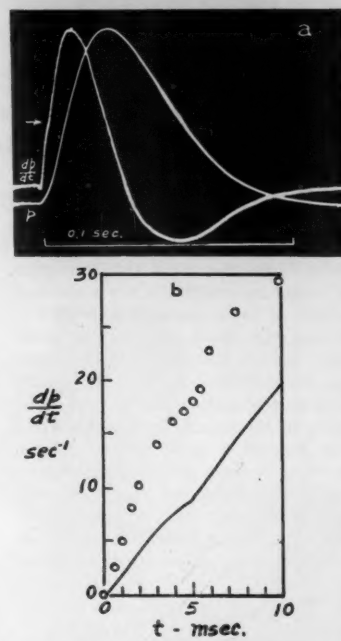


Fig. 2. (*a*) Twitch response of the same muscle as that represented in Fig. 1, showing very clear active state hump on the dp/dt curve. (*b*) Initial part of the dp/dt curves of Fig. 1, showing the active state hump on an extended time scale. Continuous line, experimental; circles, theoretical.

simple response since the active state, once brought to plateau, remains there as long as the tetanus stimulus continues. Systems involving relaxation from this plateau can be included in our theory by means of an appropriate function for the kinetics of active state decay. Making the very simple assumption that this decay is exponential with time constant α_2, a procedure like that leading to Eq. 5 yields the relevant equation,

$$\frac{dp}{dt} = \frac{b}{\lambda}\left(\frac{p+f}{p+a_0}\right)(e^{-t'/\alpha_2} - p), \qquad (9)$$

in which t' measures time from the instant at which the active state plateau ends and decay begins. If $p = 1$ at $t' = 0$, then this equation applies to muscular relaxation from maximal tetanus level. For the twitch, Eqs. 5 and 6 hold up to the moment $t' = 0$ (at which tension is still rising), and from then on Eq. 9 describes the remainder of the twitch, involving the latter part of the rise to peak, when p is always less than 1, and the subsequent relaxation period. Preliminary studies indicate that this theory yields results approximating those of actual twitch responses.

In conclusion, our work leads to the following general results: (i) a confir-

mation of the essentials of Hill's (7) conception of active muscle as a two-component system made up of contractile and series elastic components; (ii) derivation of equations that quite accurately predict the mechanics of the contraction period of an isometric tetanus; (iii) a simple method for determining the stress-strain curve of the series elastic component (though this needs confirmation by direct methods); (iv) a determination of the theoretical and experimental means for studying a newly observed feature of early contraction related to the abruptly rising phase of the active state; and (v) the general mathematical basis for study of active state mechanisms in tetanus relaxation and for the entire course of the twitch. In future research it is planned to complete the analyses regarding systems including active state relaxation, extend the theory to other types of contractions, and apply it, in general, to investigations of muscular responses under a variety of experimental conditions.

ALEXANDER SANDOW

Department of Biology, Washington Square College of Arts and Science, New York University, New York

References and Notes

1. This work was aided by grants from the Muscular Dystrophy Associations of America and by an Equipment Loan Contract No. Nonr-1559 (00) with the Office of Naval Research.
2. A. V. Hill, *Proc. Roy. Soc. (London)* **B126**, 136 (1938).
3. J. L. Petit, *Arch. intern. physiol.* **34**, 113 (1931).
4. A. V. Hill, *Proc. Roy. Soc. (London)* **B141**, 104 (1953).
5. L. Macpherson, *J. Physiol. (London)* **122**, 172 (1953).
6. D. R. Wilkie, *ibid.* **134**, 527 (1956).
7. A. V. Hill, *Proc. Roy. Soc. (London)* **B137**, 40 (1950).
8. I am thankful to Dr. Manfred Brust for performing the experimental part of this investigation.

25 November 1957

The Two Hemoglobin Components of the Chicken

Recently Saha *et al.* (*1*) reported the presence of two electrophoretically distinct hemoglobin components in the chicken, one of which showed the same mobility as the abnormal human hemoglobin E. In the course of our investigations of animal hemoglobins, we also studied the hemoglobin of the adult chicken, using different techniques. The results of this study will be reported here, for they offer some additional information.

Blood samples of over 50 different chickens (stock for slaughter) were examined first by paper electrophoresis with barbital buffer of *p*H 8.8 and of ionic strength 0.06. These analyses showed the presence of one main component (component I) with a low relative mobility and a second one (component II) with a much higher mobility. Component II, present for about 15 percent of the total amount of hemoglobin, was found in all examined animals. Its relative mobility is about the same as that of the abnormal human hemoglobin E. Our paper electrophoretic investigations confirmed therefore the results reported by Saha *et al.* (*1*).

Fig. 1. Separation of two hemoglobin fractions of the chicken on Amberlite IRC-50.

The two hemoglobin components can be separated completely by chromatography on Amberlite IRC-50 with a citrate buffer solution of *p*H 6.0 and a sodium ion concentration of 0.15 (*2*). Figure 1 represents the relative positions of the two fractions. This technique offers therefore a possibility to obtain both components separately and to compare the amino acid compositions of the two hemoglobins. For this purpose about 50 mg of each protein was hydrolyzed with 500 ml of 6*N* hydrochloric acid by boiling under reflux for 48 hours. The amino acid analyses of these hydrolyzates were achieved by the column chromatographic method of Spackman, Moore, and Stein (*3*) with the Amberlite IR 120. The results of duplicate experiments are given in Table 1. Component II contains much more of the acid amino acids (aspartic acid and glutamic acid) and much less of the basic amino acids (lysine, histidine, and arginine). The large difference in the amounts of acid and basic amino acids may explain the great difference in the electrophoretic and chromatographic behavior of the two hemoglobin fractions. Moreover, other marked differences were found. The amounts of serine, valine, and leucine are higher in component II than in the other fraction, and the amounts of alanine, isoleucine, and tyrosine are lower. The results of these amino acid analyses are therefore strongly indicative of the existence of two widely different hemoglobin types in the chicken.

Table 1. Amino acid composition of the 48-hour hydrolyzates of two hemoglobin components of the chicken. The values are given in grams per 100 g of protein.

Amino acid	Component I (g/100 g)	Component II (g/100 g)
Aspartic acid	8.8	11.25
Threonine	4.5	4.1
Serine	3.15	5.15
Glutamic acid	6.8	11.5
Proline	3.2	3.0
Glycine	3.05	2.95
Alanine	8.95	7.55
Valine	8.0	9.45
Methionine	0	0
Isoleucine	5.0	3.75
Leucine	13.2	15.0
Tyrosine	3.1	1.15
Phenylalanine	6.5	6.8
Lysine	14.55	11.8
Histidine	11.8	7.7
Arginine	7.55	4.95
Totals	108.15	106.1

It is remarkable that these two different hemoglobin types were present in all the chickens studied. This situation is different from that found in some other animals—for instance, sheep (*4*) and cattle (*5*), in which the occurrence of two different hemoglobin types seems to be controlled by a pair of allelomorphic genes, both being readily recognizable in heterozygosity. It is obvious from the amino acid analyses that both components are completely different from any human hemoglobin (*6*). Any speculation based on the occurrence of human hemoglobin E (*1*) in birds is therefore without foundation (*7*).

H. J. VAN DER HELM
T. H. J. HUISMAN

Department of Pediatrics, State University of Groningen, Groningen, Netherlands

References and Notes

1. A. Saha, R. Dutta, J. Ghosh, *Science* **125**, 447 (1957).
2. T. H. J. Huisman and H. K. Prins, *J. Lab., Clin. Med.* **46**, 255 (1955).
3. D. H. Spackman, S. Moore, W. H. Stein, in preparation; *Federation Proc.* **15**, 358 (1956).
4. H. Harris and F. L. Warren, *Biochem. J.* **60**, xxix (1955); J. V. Evans, H. Harris, F. L. Warren, *Proc. Biochem. Soc.* **42P** (1957); H. J. van der Helm, G. van Vliet, T. H. J. Huisman, *Arch. Biochem. Biophys.* **72**, 331 (1957).
5. A. D. Bangham, *Nature* **179**, 467 (1957).
6. J. H. P. Jonxis *et al.*, *ibid.* **117**, 627 (1956).
7. This investigation was supported by a grant from the Dutch Organization of Pure Research (ZWO).

21 August 1957

LEISS

Single and Double

MIRROR-MONOCHROMATORS

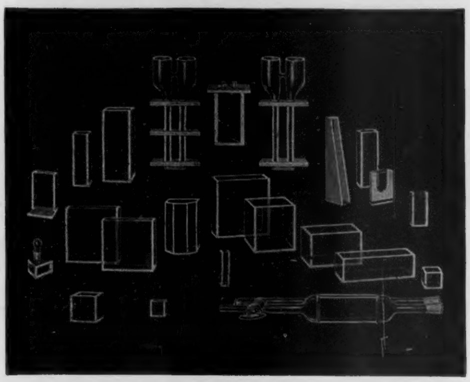
with exchangeable prisms for the visible, ultraviolet, infrared from 200 millimicrons to 20 microns

Write for Bulletin #980 to

PHOTOVOLT CORP.

95 Madison Ave. New York 16, N.Y.

GLASS ABSORPTION CELLS made by *KLETT*



Makers of Complete Electrophoresus Apparatus

SCIENTIFIC APPARATUS
Klett-Summerson Photoelectric Colorimeters—Colorimeters — Nephelometers — Fluorimeters—Bio-Colorimeters — Comparators — Glass Standards—Klett Reagents.

Klett Manufacturing Co.

179 East 87 Street, New York, New York

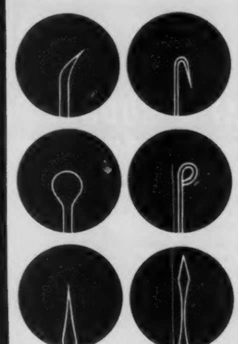
BINOCULAR
DE FONBRUNE
MICRO-FORGE

aloe

MAKE MICRO INSTRUMENTS TO YOUR SPECIFICATIONS

An indispensable accessory for all types of Micromanipulators

An endless variety of precision micro-tools is at your finger tips with this improved Micro-Forge. With little practice you can make accurate micro-probes, scalpels, pipettes, hooks and other tools.



- **Stereoscopic microscope provides an erect image**
- **38X magnification**
- **Platinum-iridium filament provides temperature range of 120 to 3000 degrees F.**
- **Air jets mounted on stage**
- **Controls for adjusting light to objective**
- **Accessory equipment including air pump, rheostats and transformer contained in base**

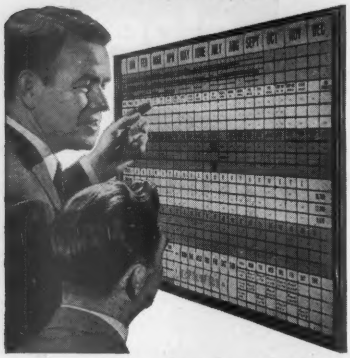
For prices and description, write for Bulletin S19-104

aloe scientific
DIVISION OF A. S. ALOE COMPANY

5655 KINGSBURY,
ST. LOUIS 12, MO.

14 FULLY STOCKED DIVISIONS FROM COAST-TO-COAST

How To Get Things Done Better And Faster



BOARDMASTER VISUAL CONTROL

★ Gives Graphic Picture — Saves Time, Saves Money, Prevents Errors
★ Simple to operate — Type or Write on Cards, Snap in Grooves
★ Ideal for Production, Traffic, Inventory, Scheduling, Sales, Etc.
★ Made of Metal Compact and Attractive. Over 60,000 in Use

Full price $49^{50} with cards

FREE 24-PAGE BOOKLET NO. BF-30 Without Obligation

Write for Your Copy Today

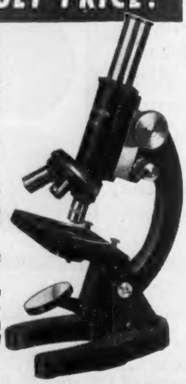
GRAPHIC SYSTEMS
55 West 42nd St. • New York 36, N.Y.

HERE'S A QUALITY STUDENT MICROSCOPE AT A BUDGET PRICE!

Although budget priced, the UNITRON Model MUS is definitely not just another student microscope. It includes these significant features often lacking in much more costly student models:

- NOT JUST a disk diaphragm ... but an iris diaphragm for perfect control of aperture.
- NOT JUST a single focusing control ... but both coarse and fine.
- NOT JUST a mirror ... but a condenser for optimum illumination and resolution.
- NOT JUST one objective ... but three: 5X, 10X, 40X.
- NOT JUST one eyepiece ... but a choice of two from 5X, 10X, 15X.

Durable, sturdy — ideally suited to withstand the use and abuse of classroom and laboratory.



Only $74 F. O. B. Destination

ASK FOR A FREE 10 DAY TRIAL

Quantity discounts start at 3 — Only $65.12 each for 25

UNITRON
INSTRUMENT DIVISION of UNITED SCIENTIFIC CO.
204-206 MILK STREET • BOSTON 9, MASS.

Please rush UNITRON's Microscope Catalog. S-4a
Name ____
Company ____
Address ____
City ____ State ____

Letters

Permafrost Research

The 29 Nov. 1957 issue of *Science* [**126**, 1099 (1957)] contains an article titled "Earth Science," prepared by Philip H. Abelson. One paragraph states: "Two problems of immense importance to survival in the Arctic are those of water and permafrost. We have two geologists working on a study of these topics. The Russians have scores." If by "we' is meant the United States, the statement is in error and should be corrected.

The U.S. Army Snow Ice and Permafrost Research Establishment conducts research on these items for the Department of Defense. Currently, 15 engineers, scientists, and technicians are employed by the Frozen Ground Basic and Applied Research Branches. Part-time work is sponsored at a number of universities utilizing about ten professional people as consultants. Contract work is also sponsored in this field, with the work done by a number of universities and private organizations.

The Arctic Construction and Frost Effects Laboratory, U.S. Army Engineer Division, New England, Corps of Engineers, has a staff of about forty engaged in the study of frozen ground and permafrost as related to military construction. They also do much of their research by means of contracts with several universities, notably Massachusetts Institute of Technology, Harvard, and Purdue.

The U.S. Geological Survey maintains a staff at Point Barrow, Alaska, and at Menlo Park, California; both are engaged in a study of the thermal gradients in permafrost under lakes, along the beaches of the Arctic Ocean, and at other locations in Alaska to measure the effect of other variable factors on the temperature regime in permafrost.

The U.S. Army Engineer Research and Development Laboratories, U.S. Army Engineer Waterways Experiment Station, the U.S. Air Force, the U.S. Navy, the Bureau of Public Roads, and the U.S. Department of Public Health all conduct substantial amounts of research in permafrost as a part of the study of particular problems which have Arctic and Antarctic applications.

The total number of technical people devoting time to a study of permafrost problems in the United States must be several score and not two as is stated. I do agree that the amount of effort spent by the Russians is more than that spent by the United States at this time and that our effort should be increased.

W. K. BOYD

U.S. Army Snow Ice and Permafrost Research Establishment, Wilmette, Illinois

I was aware of the engineering activities being carried out by the U.S. Army Snow Ice and Permafrost Research Establishment when I prepared the material which appeared in *Science* on 29 Nov. 1957.

Some of the "research" projects sponsored by W. K. Boyd's organization (as listed in the *Army Research Annual Task Summary, 1955,* vol. III, *Geophysical and Engineering Sciences*) include: "Development of methods by which troops can rapidly entrench themselves in frozen ground" ($54,000); " Development of an apparatus that will demonstrate the feasibility of applying heat to the frozen soil and progressively removing the thawed surface by a scraper" ($30,000); "Development of drilling and sampling equipment and techniques for all types of frozen ground" ($26,000).

Another "research" sponsored by one of the other organizations mentioned by Boyd: "The work consists of preliminary studies and minor investigations to determine the necessity of specific research or development relative to soil and snow mechanics" ($20,000).

Few scientists—for example, those listed in *American Men of Science*—would agree that the above examples constitute either research or science, which was the topic of our symposium.

The estimate of two geologists was incorrect, though it was provided me by one of the leading hydrologists of this country. The actual number is at least 13—11 engaged in mapping arctic areas, 2 in laboratory and theoretical research studies.

Neither Boyd's remarks nor this altered estimate change the conclusion that Russian scientific activity in the Arctic far exceeds our own.

PHILIP H. ABELSON

Carnegie Institution of Washington, Washington, D.C.

Multilingual Reporting of Scientific Data

Science, in principle, is an international undertaking. The results of scientific inquiry are published and thus made a common property of mankind or, more precisely, of those scientists who can read the language in which the work has been written. For a variety of reasons (the large volume of printed matter on almost any subject being the most cogent one), the typical scientist cannot aspire to be a polyglot, mastering all of the European languages, much less all of the Oriental. He has to rely on his helpers—the writers of abstracts, "excerpts," and reviews, on second-hand information.

The usefulness of a scientific paper, written in a language understandable only to a limited audience, is substantially increased by the attachment of an

informative synopsis in one or more world languages. In time, perhaps, the *Interlingua* will serve for this purpose as the universal language of scientific summaries and will thus restore, to some extent, the intellectual unity of the Western world, lost with the replacement of Latin by national tongues. In smaller countries, still wishing to be heard in the international forum, a program for providing technical help in the preparation of idiomatically correct synopses and abstracts of scientific publications would fully deserve the attention of the local academies of science.

There is another important step that the author (and the publisher) can take in the interest of making a scientific communication more widely and more thoroughly intelligible—namely, presentation of legends, table headings, and graph labels in a language of world-wide currency. In particular, we have stressed this point for years to our Japanese colleagues and friends.

It has been a real pleasure to see in a recent paper on the anthropological differences between population groups in Czechoslovakia [V. Fetter, *Ceskoslov. Ethnograf.* **5**, 217 (1957)] the consistent use of both Russian and English, in addition to Czech, in tables and graphs. In sciences which operate with quantitative data, the tables and graphs contain, as a rule, the essential new information. Together with a clear verbal summary of conditions and methods, the presentation of tabular and graphic material in a form intelligible to the majority of scientists will go a long way toward removing the curse of nationalism and provincialism in scientific publications.

In works which rely heavily on pictorial documentation, such as Hess' atlas [W. R. Hess, *Hypothalamus und Thalamus* (Thieme, Stuttgart, 1956)], the use of bilingual legends may be both preferable on purely scientific grounds and more economical in the long run.

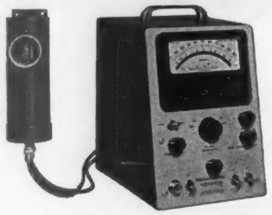
JOSEF BROZEK
University of Minnesota

"Psychozoa"

In the note by William L. Straus, Jr., on "Evolutionary terminology" [*Science* **127**, 22 (3 Jan. 1958)], there unfortunately occurs a protest about Huxley's use of the term *Psychozoa* for man, presumably on the ground that our social world's state today does not indicate anagenesis with reference to man, but the opposite. If, by what Straus terms the "increasing disintegration of human interpersonal and intersocial relations," he refers to the radical alteration of social affairs in our time, this might very well be cited as evidence of the adaptability of the type and, possibly, as leading to its "biological improvement." The

New UNIVERSAL PHOTOMETER

For Low Level Light Measurements



WITH THE MODEL PH 200

* **Luminous Sensitivity:** $>10^{-10}$ *Lumens*
* **Amplifier Stability:** *Better than 0.1% Full Scale after warmup*
* **Reliability:** *Signal circuitry involves only one vacuum tube*
* **Range:** *Density — 0 to 6; Transmittance — 10^{-6} to 1.0*

The Model PH 200 Photomultiplier Photometer uses the latest circuit techniques to provide the most reliable and flexible photometer commercially available. The instrument is designed to operate with all types of photomultiplier or phototubes and includes an adjustable high voltage supply. An output jack is provided on the rear chassis for driving an oscilloscope or recorder.

Price: $495.00 including detector and photomultiplier tube type 931A.

Write for complete technical information. Address Dept. S4 3

Eldorado Electronics

2821 Tenth Street • Berkeley 10, Calif.

THE LUMINESCENCE OF BIOLOGICAL SYSTEMS

edited by Frank H. Johnson

6" x 9", clothbound, 466 pp., genera and species, subject and author indexes, bibliographies

$7.00 ($6.00 for cash orders by AAAS members)

"The recent rapid development of bio-luminescence is well illustrated by the book and it should hasten the transition of the field from a highly specialized area to one having many points of contact with other parts of both physiology and chemistry." ***American Scientist,*** **Autumn 1956.**

The volume includes papers and discussion on fundamental aspects of "cold light" given at a recent international conference. Leading investigators provide a critical evaluation of current knowledge while exploring approaches to unsolved problems. The free interchange of ideas in the discussions intensifies the stimulating nature of the book.

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

1515 Massachusetts Ave., NW, Washington 5, D.C.

"disintegration" of a social order is not necessarily to be interpreted as evidence for nonanagenesis in man, nor is it to be considered as sufficient grounds for withholding the accolade—if such it is—of "Psychozoa" from man.

CHESTER W. HARTWIG
Alabama Polytechnic Institute, Auburn

Dr. Chester W. Hartwig seems to have misinterpreted the reason for my protest against Julian Huxley's coinage of the taxonomic category "Psychozoa" for man. His misinterpretation can perhaps be traced, at least in part, to an unfortunate misprint by which my original "intersocietal" was altered to "intersocial." I thus was not referring to "the radical alteration of social affairs in our time" but, rather, to the frightening disintegration of relations between nations and international coalitions, a disintegration that actually threatens the very existence of the human species. The evolution of man until 1914 may well have been one of increasing adaptedness and so-called biological improvement—hence, "anagenetic"; but one may justifiably wonder whether it has not been going in the opposite direction since that time. Indeed, if one were inclined to coin a bit of the evolutionary jargon against which I protest, he might will be tempted to label man's recent evolution "katagenetic."

WILLIAM L. STRAUS, JR.
Johns Hopkins University, Baltimore, Maryland

Worms, Dogs, and Paramecia

The current debate in *Science* between Gelber (*1*) and Jensen (*2, 3*) concerning the learning ability of paramecia focuses attention upon a new version of an old argument. In a series of experiments begun some ten years ago, Gelber (*4*) has sought to discover whether *Paramecia aurelia* can be conditioned. She employed a typical conditioned-response paradigm. Following the replication of some of her studies, Jensen has maintained that the data do not demonstrate learning but are better accounted for by chemical processes. To clarify her findings, Gelber (*1*) has drawn the analogy between a hungry dog approaching a steak and paramecia swimming toward food-bacteria. A more apt comparison, thinks Jensen (*3*), would be "that of an earthworm which crawls and eats its way through the earth, blundering onto food-rich soil and avoiding light, heat, and dryness." The situation has its humorous aspects.

The basic question at issue may be stated in more general terms in the form of two conflicting hypotheses. (i) The hypothesis espoused by Gelber is that the ability to learn or to modify behavior with practice is a function of all living tissue. It should therefore be demonstrable not only in paramecia but in other low organisms as well. (ii) The hypothesis espoused by Jensen is that learning ability is possessed only by animals relatively high in the phyletic scale and that the behavior of lower forms must be accounted for in terms of reflexes, tropisms, and so on—that is, mechanically. Comparative psychologists and students of animal behavior will recognize in these two viewpoints a dichotomy which has existed in one form or another for centuries. Sometimes it has been given a religious flavor, the line being drawn between man, who possesses reason, a soul, and other high powers, and animals below man, which are lacking in one or more of these attributes. Such great names as those of Aristotle, Thomas Aquinas, Descartes, and Jasques Loeb have been associated with this problem.

Perhaps more to the point in the present controversy is the citation of relevant literature on the learning (and nonlearning) of lower organisms. It appears not to have occurred either to Gelber or to Jensen that they might have bolstered their cases in this way. Day and Bentley (*5*), for example, have reported that they got learninglike behavior in paramecia in a situation which was entirely different from that of the Gelber experiment. The Day and Bentley study was duplicated by Stevenson Smith (*6*), who supported the major findings in almost every detail. Learned avoidance responses to heat, cold, and ultraviolet light have been observed independently by Bramstedt (*7*), Soest (*8*), and Tschakhotine (*9*). A different type of investigation, by French (*10*), gives seemingly unequivocal evidence of trial-and-error learning in paramecia. Appropriate controls ruled out any question that the change in behavior with repeated trials might have been due to chemical effects or to fatigue.

Reported examples of learned behavior in other primitive organisms also bear upon the argument. According to Warden, Warner, and Jenkins (*11*), the common marigold, which opens to light and closes to darkness, can be "trained" to a particular rhythm of opening and closing by repeated exposure to alternating light and dark periods of the desired frequency. Gibbs and Dellinger (*12*) noted activity in *Amoeba proteus* which they considered to be learned, and Mast and Pusch (*13*) succeeded in training *Amoeba* to make an anticipatory avoidance response to a beam of light. In describing the research of N. N. Plaviltschikob on the conditioning of 82 colonies of infusoria, *Carchesii lachmani,* Razran (*14*) has referred to this work as "the most extensive single experiment in the conditioning of any organism."

These studies constitute a considerable

mass of evidence in support of the Gelber interpretation—evidence which can hardly be brushed aside. The negative examples (and there are some) I will leave for Jensen or for someone else. In the light of such observations, however, one wonders if there is any logical or biological reason why paramecia should not be capable of forming simple associations. Could it be that the opponents of this view are unwittingly motivated by their own anthropocentrism or by an emotional bias that this "just ought not to be so"?

As for the worms, there is plenty of evidence that they, too, can modify their behavior with practice. If Jensen's allusion to them was meant to imply that they are unable to do so, it was ill-advised. One of the classic experiments in comparative psychology is the demonstration of learning, retention, and negative transfer in the manure worm, *Allolobophora foetida*, by Yerkes in 1912 (*15*). In 1955 Thompson and McConnell (*16*) successfully conditioned the planarian, *Dugesia dorotocephala*, and Schmidt (*17*) has shown that two other species of worms, one of which was the earthworm, *Lumbricus terrestris*, can readily learn a single-unit T-maze. Other studies of learning in earthworms have been published by Robinson (*18*), Bharucha-Reid (*19*), and Arbit (*20*)—the latter in 1957. Of course the earthworm avoids light, heat, and dryness, as Jensen points out. But dogs—and even human beings, I might add—have been known to display avoidance behavior in situations where electric shock, excessive heat, or other noxious or damaging stimuli are present.

W. N. KELLOGG
*Department of Psychology,
Florida State University, Tallahassee*

References

1. B. Gelber, *Science* 126, 1340 (1957).
2. D. D. Jensen, *ibid.* 125, 191 (1957).
3. ———, *ibid.* 126, 1341 (1957).
4. B. Gelber, *J. Genet Psychol.* 88, 31 (1956); *J. Comp. and Physiol. Psychol.* 49, 590 (1956).
5. L. M. Day and M. Bentley, *J. Animal Behavior* 1, 67 (1911).
6. S. Smith, *J. Comp. Neurol.* 18, 499 (1908).
7. F. Bramstedt, *Z. vergleich. Physiol.* 22, 490 (1935).
8. H. Soest, *ibid.* 24, 720 (1937).
9. S. Tschakhotine, *Arch. inst. prophylactique, Paris* 10, 119 (1938).
10. J. W. French, *J. Exptl. Psychol.* 26, 609 (1940).
11. C. J. Warden, T. N. Jenkins, L. H. Warner, *Introduction to Comparative Psychology* (Ronald Press, New York, 1934), p. 238.
12. D. Gibbs and O. P. Dellinger, *Am. J. Psychol.* 19, 232 (1908).
13. S. O. Mast and L. C. Pusch, *Biol. Bull.* 46, 55 (1924).
14. G. H. S. Razran, *Psychol. Bull.* 30, 262 (1933).
15. R. M. Yerkes, *J. Animal Behavior* 2, 332 (1912).
16. R. Thompson and J. McConnell, *J. Comp. and Physiol. Psychol.* 48, 55 (1955).
17. H. Schmidt, Jr., *Science* 121, 341 (1955).
18. J. S. Robinson, *J. Comp. and Physiol. Psychol.* 46, 262 (1953).
19. R. P. Bharucha-Reid, *Science* 123, 222 (1956).
20. J. Arbit, *Science* 126, 634 (1957).

Meetings

Bioanalysts

The American Association of Bioanalysts, recently affiliated with the AAAS, is a scientific society formed in 1956 by a merger of the National Association of Clinical Laboratories and the Council of American Bioanalysts. Its membership is composed of those engaged in the analytical fields of biological sciences, either as bioanalysts or as teachers of the sciences of biochemistry, bacteriology, serology, or parasitology.

For administrative purposes the organization has four regional divisions which take in the whole United States. Each of these conducts scientific meetings and seminars of its own. Over-all national direction is maintained by a board of directors serving in the dual role of national and regional officers.

All scientific activities and projects are under the jurisdiction of the scientific council. These consist of scientific meetings of all types, ranging from

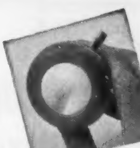
PACKARD FLOW COUNTERS

for Geiger and Proportional Operation

Windowless and Flo-Window Types

Windowless

Model 200A



Flo-Window

Model 210

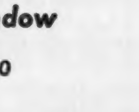
1 Windowless Flow Counter provides maximum sensitivity for counting solid samples which emit very soft radiations. Common examples are counting alpha particles or low energy betas from isotopes such as carbon-14 and sulphur-35.

2 The sample is introduced directly into the counting chamber. There is no window of any sort interposed between the radioactive material and the active counting volume of the chamber. Full 2π geometry is achieved.

1 Flo-Window Counter is used primarily for beta counting. Sensitivity for low energy radiation is slightly less than with the Windowless Flow Counter, but greater than with sealed counters using the thinnest possible mica windows. The very thin plastic window prevents undersirable effects sometimes encountered with internal counting.

2 Where adverse sample factors might cause erratic windowless counting, the Flo-Window Counter should be used. Extremely good reproducibility and stability can thus be achieved with only a slight loss in sensitivity.

For complete details send card or letter requesting illustrated 4-page Bulletin 200.



Packard Instrument Company

DEPT. A • P. O. BOX 428 • LA GRANGE, ILLINOIS

formal papers to seminars and discussions, and active participation in university training programs for technicians and bioanalysts, maintained by apprentice training and workshop demonstration.

The most notable formal meeting of the year is the Margaret Beattie lecture, presented annually. Margaret Beattie lecturers of previous years have been Maxwell Wintrobe, Linus Pauling, and Hans Frankel-Conrat. The lecturer for 1958 will be Edward Teller. Presented on a broad academic plane, the lecture is designed to bring current research knowledge to the analytic field.

A quarterly, *The Abstracts of Bioanalytic Technology*, is published through the professional abstracting service of the John Crerar Library in Chicago, Illinois. The material covered pertains to clinical laboratory testing, both in the research and applicatory phases. The addition of a new section titled "Bioanalysis" has been authorized to expand this journal, and a board of editors has been selected. This group is now accepting original papers for publication.

Major scientific emphasis is placed upon evaluation studies covering methods, primary standards, and laboratories of the members. This is a cooperative enterprise which provides calibrating standards and test materials. A group of pretest laboratories prepares technically standardized reagents and inquiries into causes of variation. Results are returned to member participants and summarized during the national meeting.

A legislative council assembles information on current legislation that affects the professional status of the membership. At present, practicing bioanalysts are licensed in New Jersey, California, Florida, and Pennsylvania. Many other states have voluntary supervision by the respective boards of public health. Cooperation between association members and state enforcement groups has effected an excellent liaison between the licensee and the administrative agency.

The association is a member of the Intersociety Committee on Laboratory Services Related to Health. Its internal organization, particularly the legislative council, is well adapted for assembling and collating material for intersociety discussion. The committee promises to be a forum for active debate of many issues vital to the bioanalyst.

Communication within the association is maintained by a newsletter, *The Bulletin*, published quarterly.

President Chernaik has just announced the appointment of William Reich as delegate to the AAAS council. Reich is eminently qualified to present the position and problems of the bioanalyst. He is a practicing clinical laboratory bioanalyst in California and is presently a candidate for a doctor's degree in public health at the University of California in Berkeley.

The 1958 national meeting is scheduled to be held in the Hotel New Yorker, New York City, 24 to 27 April.

Lucien D. Hertert
American Association of Bioanalysts, San Francisco, California

Eastern Colleges Conference

The twelfth annual Eastern Colleges Science Conference will be held at Wilkes College 17, 18, and 19 April. More than 80 colleges will participate (including Yale, Columbia, Dartmouth, Cornell, Temple, and Georgetown). Among the featured speakers are William C. H. Prentice, dean of Swarthmore College, and Gustav A. Swanson, head of the conservation department at Cornell University. The program will include the presentation of student research papers, exhibits and chemical companies, tours of local industries, and a banquet and dance.

Society of General Physiologists

The Society of General Physiologists will hold its annual meeting at the Marine Biological Laboratory, 9–11 June. Contributed papers and the business meeting are scheduled for the first day. A symposium on "Subcellular Particles and Their Function" has been organized by Teru Hayashi of Columbia University. A foreign participant, Christian DeDuve, University of Louvain, Louvain, Belgium, will present a paper on "The Biochemistry and Physiology of the Lysosomes." Dormitory accommodations may be obtained by writing *before 1 May* to Mrs. Lila S. Meyers, Marine Biological Laboratory, Woods Hole, Mass.

Genetics in Medical Research

World genetics experts will gather on the University of Wisconsin campus 7–10 April for a Symposium on Genetics in Medical Research. The symposium will stress the growing importance and recognition of genetics in medical research in the United States. Financial support is being provided by a grant from the National Heart Institute.

The symposium will bring together an outstanding group of geneticists for informal technical discussions and exchange of ideas. It will also acquaint medical researchers with geneticists and genetic developments of importance to medicine. Specialists from England, Scotland, Sweden, France, Italy, and Japan are scheduled to speak, along with representatives from universities and research centers in the United States.

The conference is co-sponsored by the department of genetics in the university's College of Agriculture and the new department of medical genetics in the Wisconsin Medical School. John Z. Bowers, dean of the Medical School, is chairman and Joshua Lederberg, chairman and professor of medical genetics, is corresponding secretary of the meeting.

Foreign participants include: C. A. Clarke, Liverpool University, Liverpool; Bruce Stocker, Lister Institute, London; R. Ceppelini, of Milan, Italy (at present serving as visiting investigator at Columbia University); L. L. Cavallia-Sforza, University of Pavia, Milan; G. Pontecorvo, University of Glasgow, Scotland; B. Ephrussi, Laboratory of Physiological Genetics, CNRS, Seine-at-Oise, France; George Klein, Karolinska Institutet, Stockholm, Sweden; Ei Matsunaga, Sapporo Medical College, Hokkaido, Japan.

Some 120 to 140 scientists are expected for the symposium. Included in the registration, in addition to countries represented on the program, are delegates from Canada and Australia. Every medical school in the United States has been invited to send representatives, and preliminary registration indicates some two-thirds will be represented.

Chemical Engineering

Jets and rockets, the status of technical education in America, energy sources of tomorrow, atomic energy, and the problem of industrial noise are some of the subjects that will be considered during a Canada-United States Chemical Engineering Conference that will take place 20–23 April at the Sheraton-Mount Royal Hotel in Montreal. The conference is sponsored by the American Institute of Chemical Engineers and the Chemical Institute of Canada. More than 700 people are expected to attend. The program will open with a symposium on chemical engineering education in the United States and Canada, with Walter G. Whitman, Massachusetts Institute of Technology, as moderator. The conference secretary is F. K. Rogers, c/o Shawinigan Chemicals Limited, Box 6072, Montreal, Canada.

Hormones and Atherosclerosis

A conference on Hormones and Atherosclerosis was held on 12, 13, and 14 March in Brighton, Utah, near Salt Lake City, under the auspices of the National Heart Institute's Endocrinology Study Section, for the purpose of evaluating data. Gregory Pincus, director of research at the Worcester Foundation

for Experimental Biology was chairman. About 45 were present, including two delegates from England, two from Scotland, one from South Africa, and one from Sweden.

Society Elections

■ Beta Beta Beta (biological society): pres., George H. Mickey, Louisiana State University; sec.-treas., Frank G. Brooks, Box 336, Madison Square Station, New York 10, N.Y. The vice presidents are H. P. Sturdivant, Western Maryland College; E. C. Cooke, Wake Forest College; Ted F. Andrews, Kansas State Teachers College; Dixie Young, Texas Woman's University; F. Albert Ellis, Department of Natural Sciences, San Jose State College; Boyd B. Palmer, Inter-American University, Puerto Rico. The representatives to the AAAS Council are George H. Mickey of Louisiana State University and Bernal Weimer of Bethany College.

■ Northwest Scientific Association: pres., William K. Ferrell, Department of Forestry, Oregon State College; v. pres., Mark F. Adams, Institute of Technology, State College of Washington; sec.-treas., Willis B. Merriam, Department of Geography, State College of Washington.

■ National Association of Biology Teachers: pres., Irene Hollenbeck, Southern Oregon College; past pres., John Breukelman, State Teachers College, Emporia, Kansas; pres.-elect, Paul Klinge, Indiana University; sec.-treas., Paul Webster, Bryan City Schools, Ohio. The vice presidents are Dorothy Matala, Iowa State Teachers College, Irving C. Kenne, Brookline High School, Brookline, Mass., and Robert Smith, DeKalb High School, Ill. Representatives to the AAAS Council are George W. Jeffers and John Breukelman.

■ American Council on Pharmaceutical Education: pres., George D. Beal, Pittsburgh, Pa.; v. pres., Joseph B. Burt, Lincoln, Neb.: sec.-treas., Patrick H. Costello, 77 West Washington St., Chicago 2, Ill.

■ American Psychological Association: pres., Harry F. Harlow, University of Wisconsin; pres.-elect, Wolfgang Köhler, Swarthmore College; past pres., Lee J. Cronbach, University of Illinois; recording sec., Launor F. Carter, System Development Corporation, Santa Monica, Calif.; treas., Meredith P. Crawford, Human Resources Research Office, Washington, D.C.; executive sec., Roger W. Russell, Washington, D.C. The representatives to the AAAS Council are James J. Gibson, Department of Psychology, Cornell University, and Frank W. Finger, Psychological Laboratory, University of Virginia.

Forthcoming Events

April

25–26. American Assoc. of University Professors, annual, Denver, Colo. (R. K. Carr, 1785 Massachusetts Avenue, NW, Washington 6.)

25–26. Georgia Acad. of Science, annual, Emory Univ., Emory. (M. T. Clark, Chemistry Dept., Emory Univ., Emory, Ga.)

25–26. Kentucky Acad. of Science, Natural Bridge State Park. (G. Levey, Berea College, Berea, Ky.)

25–26. Louisiana Acad. of Sciences, annual, Shreveport. (H. B. Boudreaux, Louisiana State Univ., Baton Rouge 3.)

25–26. South Dakota Acad. of Science, annual, Rapid City. (J. M. Winter, Botany Dept., Univ. of South Dakota, Vermillion.)

27–1. American Ceramic Soc., 60th annual, Pittsburgh, Pa. (C. S. Pearce, ACS, 4055 N. High St., Columbus 14, Ohio.)

27–1. Electrochemical Soc., spring, New York. (H. B. Linford, ES, 1860 Broadway, New York 23.)

27–1. Society of American Bacteriologists, 59th annual, Chicago, Ill. (E. M. Foster, Univ. of Wisconsin, Madison 6.)

27–1. Southwestern and Rocky Moun-

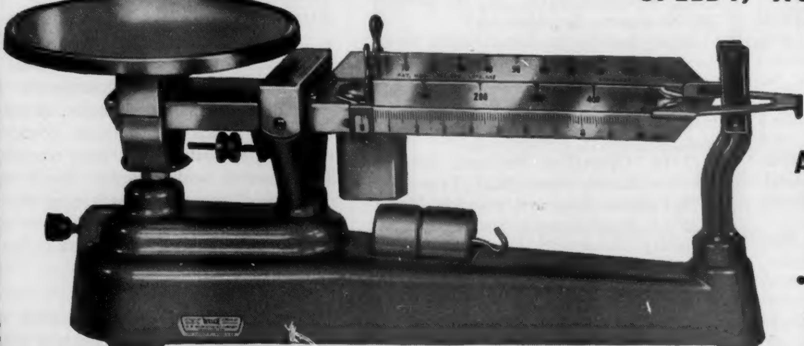
• Convenient • Efficient • Economical

Welch **TRIPLE-BEAM TRIP-SCALE**

• *Large Capacity-1610 Grams* (With Extra Weight - 2110 Grams)

• *Sensitivity to 0.1 Gram*

SPEEDY, ACCURATE WEIGHING



No. 4048

Rugged, Compact Construction

All Exposed Parts of *Stainless Steel*

• Wide Range • Stable • Corrosion-Resistant • Low Cost

3 Graduated Scale Levels for easy reading. Riders move easily. Hard, Cobalite Knife Edges maintain true edge indefinitely.

Grooved Agate Bearings are protected against damage, yet highly resistant to corrosive action of laboratory fumes.

One-Piece Beam Construction—Silver-Gray Hammerloid Finish
Rapid Zero Setting—Beam Arrest for faster weighing.

No. 4048 LOW FORM, PRICE, WITH TWO EXTRA WEIGHTS $21.00
No. 4048C. PLASTIC COVER, For No. 4048 .... Each, $0.90
No. 4048W. EXTRA WEIGHT. For increasing the capacity of No. 4048 to 2110 grams .... Each, $1.45

W. M. WELCH SCIENTIFIC COMPANY
DIVISION OF W. M. WELCH MANUFACTURING COMPANY
ESTABLISHED 1880
1515 Sedgwick Street, Dept. E Chicago 10, Illinois, U. S. A.
Manufacturers of Scientific Instruments and Laboratory Apparatus

tain Div., AAAS, annual, Las Vegas, N.M. (M. G. Anderson, New Mexico A.&M. College, Las Cruces.)

28–29. Automatic Control in the Petroleum and Chemical Industries, 3rd annual conf., Norman, Okla. (M. L. Powers, Extension Div., Univ. of Oklahoma, Norman.)

28–3. Engineering Societies of Western Europe and the United States, conf. (closed), New York. (C. E. Davies, American Soc. of Mechanical Engineers, 29 W. 39 St., New York 18.)

May

1–3. American Physical Soc., Washington, D.C. (K. K. Darrow, APS, Columbia Univ., New York 27.)

1–3. Kansas Acad. of Science, annual, Ottawa. (C. T. Rogerson, Dept. of Botany, Kansas State College, Manhatten.)

1–3. Midwestern Psychological Assoc., Detroit, Mich. (D. W. Fiske, Dept. of Psychology, University of Chicago, Chicago 37).

1–8. American Soc. of Tool Engineers, 26th annual, Philadelphia, Pa. (ASTE, 10700 Puritan, Detroit 38, Mich.)

2. Engineers and Architects Conf., 5th annual, Columbus, Ohio. (H. A. Bolz, College of Engineering, Ohio State Univ., Columbus.)

2. Southern California Acad. of Sciences, annual, Los Angeles. (Miss G. Sibley, Los Angeles County Museum, Exposition Park, Los Angeles 7, Calif.)

2–3. Minnesota Acad. of Science, Bemidji. (M. R. Boudrye, 51 University Ave., St. Paul 3, Minn.)

2–3. North Carolina Academy of Science, annual, Durham. (J. A. Yarbrough, Meredith College, Raleigh, N.C.)

2–3. North Dakota Academy of Science, 50th anniversary, Fargo. (B. G. Gustafson, Box 573, University Station, Grand Forks, N.D.)

3–4. Population Assoc. of America, annual, Chicago, Ill. (D. O. Price, Inst. for Research in Social Science, Univ. of North Carolina, Chapel Hill.)

4–7. American Federation for Clinical Research, annual, in conjunction with American Soc. for Clinical Investigation and Assoc. of American Physicians, Atlantic City, N.J. (W. W. Stead, College of Medicine, Univ. of Florida, Gainesville.)

5–6. Secondary Recovery Symp., 3rd biennial, Wichita Falls, Tex. (E. O. Kirkendall, American Inst. of Mining, Metallurgical & Petroleum Engineers, 29 W. 39 St., New York 18.)

5–7. American Geophysical Union, 39th annual, Washington, D.C. (W. E. Smith, AGU, 1515 Massachusetts Ave., NW, Washington 5.)

5–7. Microwave Theory and Techniques Symp., Stanford, Calif. (G. H. Keitel, 601 California Ave., Palo Alto, Calif.)

5–8. American Meteorological Soc., Washington, D.C. (K. C. Spengler, AMS, 3 Joy St., Boston 8, Mass.)

6–9. Optics in Metrology Colloquium, International Commission of Optics, IUPAP, Brussels, Belgium. (S. S. Ballard, Scripps Institution of Oceanography, San Diego 52, California.)

6–9. Royal Netherlands Acad. of Sciences and Letters, 150th anniversary, Amsterdam, Netherlands. (RNASL, 29 Kloveniersburgwal, Amsterdam.)

6–9 Western Joint Computer Conf., Los Angeles, Calif. (W. H. Ware, Rand Corp., 1700 Main St., Santa Monica, Calif.)

6–9. International Commission of Optics, colloquium, Brussels, Belgium. (W. D. Wright, Imperial College, South Kensington, London, S.W.7.)

7–9. Acoustical Soc. of America, annual, Washington, D.C. (W. Waterfall, 335 E. 45 St., New York 17.)

7–10. Virginia Academy of Science, annual, Roanoke. (P. M. Patterson, Dept. of Science, Hollins College, Hollins, Va.)

7–11. American Psychoanalytic Assoc., San Francisco, Calif. (J. N. McVeigh, APA, 36 W. 44 St., New York 36.)

8. Association of Vitamin Chemists, Chicago, Ill. (A. E. Denton, Research Labs., Swift & Co., Chicago 9.)

8–9. Colorado-Wyoming Acad. of Science, annual, Denver, Colo. (R. G. Beidleman, Zoology Dept., Colorado College, Colorado Springs.)

8–10. Illinois State Academy of Science, 51st annual, Urbana. (R. A. Evers, Illinois Natural History Survey. Urbana.)

11–16. Social Welfare, natl. conf., Chicago, Ill. (National Conf. on Social Welfare, 22 W. Gay St., Columbus 15, Ohio.

12–14. High Polymer Forum, 8th Canadian, Ste. Anne de Bellevue, Quebec. (M. H. Jones, Dept. of Chemistry, Ontario Research Foundation, 43 Queens Park, Toronto 5, Ont.)

12–14. Instrumental Methods of Analysis, internatl. Symp., Houston, Tex. (H. S. Kindler, Instrument Soc. of America, 313 Sixth Ave., Pittsburgh, Pa.)

12–14. Research Methods and Instrumentation Symp., 8th annual, Bethesda, Md. (J. B. Davis, National Institutes of Health, Bethesda 14.)

12–16. American Psychiatric Assoc., annual, San Francisco, Calif. (D. Blain, APA, 1785 Massachusetts Ave., NW, Washington 6.)

14. American Acad. of Arts and Sciences, Brookline, Mass. (R. W. Burhoe, 280 Newton St., Brookline 46.)

14–16. Society for Experimental Stress Analysis, Cleveland, Ohio. (W. M. Murray, P.O. Box 168, Cambridge 39, Mass.)

14–24. European Acad. of Allergy, The Hague, Netherlands. (EAA, 17 Emmalaan, Utrecht, Netherlands.)

15–16. Operations Research Soc. of America, Boston, Mass. (M. L. Ernst, Box 2176, Potomac Station, Alexandria, Va.)

15–17. Basal Ganglia Surgery for Involuntary Movement Disorders, symp., New York. (Miss D. P. Frome, Office of Public Relations, New York University-Bellevue Medical Center, 550 First Ave., New York 16.)

18–24. Sanitary Engineering, 6th Inter-American Cong., San Juan, Puerto Rico. (E. Ortega, Box 218, San Juan.)

19–21. American Trudeau Soc., 53rd annual, Philadelphia, Pa. (K. R. Boucot, Woman's Medical College, Philadelphia.)

19–23. Gas Chromatography, 2nd symp., Amsterdam, Netherlands. (G. Dijkstra, Postbox 114, Vlaardingen, Netherlands.)

(See issue of 21 March for comprehensive list)

Equipment

The information reported here is obtained from manufacturers and from other sources considered to be reliable. Science does not assume responsibility for the accuracy of the information. A coupon for use in making inquiries concerning the itmes listed appears on page 774.

■ AUTOMATIC BURETTES require no lubrication to prevent frozen connections. Both plug and bushing are made of Teflon. In addition, the ground surfaces into which the plug fits are treated during manufacture to produce a bonded bearing surface. Graduated sections are of precision-bore tubing and are graduated to meet National Bureau of Standards specifications. (Scientific Glass Apparatus Co., Dept. S972)

■ PORTABLE COLORIMETER permits measurements in the field of color and luminosity of near or distant objects. Weight, including all accessories, is 47 lb. The instrument employs an additive color-matching process with red, blue and green filters as standards. The comparison field comprises an annular field, representing the color to be measured, surrounding a concentric circular area of adjustable color. (Eastman Kodak Co., Dept. S975)

■ HYDROCARBON DETECTOR, to warn of presence of excessive hydrocarbon in clean compressed gas, consists of a dark-field illumination system built into a windowed pressure vessel. A multiplier phototube detects light scattered from aerosol impurities carried by the gas stream. A relay operated by the phototube current shuts off equipment or actuates an alarm. The equipment can be used at pressures up to 100,000 lb/in². (American Instrument Co., Inc., Dept. S977)

■ CHROMATOGRAM SCANNER rotates a drum-mounted radiochromatogram in front of a collimated detector. A ratemeter to which the detector connects drives a pen-writing rectilinear recorder. The scanner and recorder drives are mechanically coupled. Strips up to 56 cm long and 3.5 cm wide can be placed on the drum. (Atomic Accessories, Inc., Dept. S978)

■ VACUUM OVEN, for determination of loss of weight on heating, heats a sample distributed over an aluminum-powder extender in vacuum. A current of air or inert gas, dried to a water content not exceeding 0.0007 mg/lit, is bled over the sample surface. Gas flow may be controlled and measured between 0.5 and 100 ml/min by means of a soap-film flowmeter. Temperature is controlled up to 110° ± 1°C. (Griffin & George Ltd., Dept. S986)

■ TIME-LAPSE DRIVE UNIT for use with motion-picture camera may be externally pulsed at random intervals or may be synchronized automatically with any event which can be made to throw a switch. An internal timer provides a frame repetition rate of 1/min. This standard rate can be altered by changing motors and gear trains. Removal or attachment of the drive unit does not require dismounting the camera. (Electro-Mechanical Development Co., Dept. S983)

■ INFORMATION STORAGE SYSTEM consists of a magnetic drum, a drive and lubrication system, a 3 by 10 by 10 track-selection mercury-relay matrix, a pre-amplifier, and a final writing amplifier. The drum is 15 in. in diameter by 14 in. long. Storage density is 1040 bits/in. on 320 tracks with a total capacity of 15×10^6 bits. Average access time is 180 msec. (Laboratory for Electronics, Inc., Dept. S984)

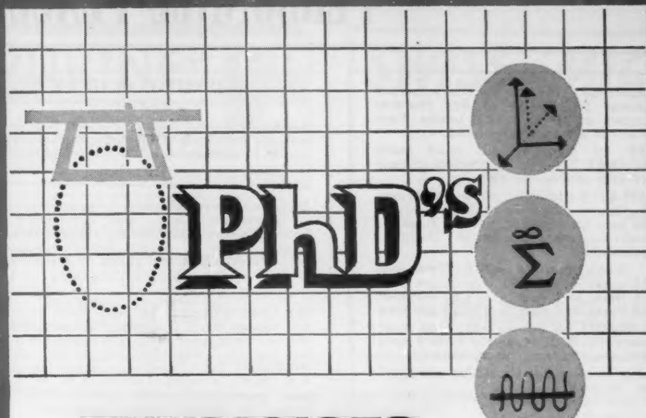
■ AUTOMATIC-RECORDING BALANCE combines the range and accuracy of a standard analytical balance with automatic operation and recording. Capacity of the balance is 200 g, accuracy and readability ± 0.1 mg. Full-scale deflection on the 11-in. recorder chart represents 110 mg. The balance automatically adds or subtracts weights as required to maintain the recorder pen on scale. The range of automatic control of weights is 4 g. The sample can be placed on the balance pan or suspended in a controlled environment above or below the balance. (Wm. Ainsworth & Sons, Inc., Dept. S985)

■ FREQUENCY METER allows direct reading of frequencies in waveguide systems operating between 5100 and 5900 Mcy/sec. The instrument consists of a cavity resonator tuned by a noncontacting plunger. Spiralled around a drum dial is a 4-ft scale calibrated directly in frequency. (Polytechnic Research & Development Co., Inc., Dept. S987)

■ ATOMIC LABORATORY designed for high-school and college science instruction is a commercial version of equipment assembled originally for the AEC science-teacher training program. The equipment includes a scaler-ratemeter and a range of accessories for a variety of experiments. (Nucleonic Corporation of America, Dept. S981)

■ HIGH-TEMPERATURE FURNACE operates at temperatures up to 4500°F for short periods. Working space is 2 in. in diameter by 12 in. long. The furnace is self-contained and operates on 220-v single phase power, drawing 13.4 kw. (Harry W. Dietert Co., Dept. S982)

JOSHUA STERN
National Bureau of Standards



PHYSICISTS
MATHEMATICIANS
ENGINEERS, EE

Research-minded individuals with high qualifications and keen interest in communications theory are invited to review the scope of the studies described below with a representative of

SYLVANIA'S AMHERST LABORATORY
(in beautiful suburban Buffalo)

PROBABILITY AND INFORMATION THEORY

Studies in broad field of probability theory and its application to information theory. Aimed at advancing the state of the art in communications.
Ph.D. in mathematics, theoretical statistics or information theory with strong mathematical background.

ELECTROMAGNETIC PROPAGATION

Experimental and theoretical research in electromagnetic propagation as related to new concepts and developments in the means and techniques of communications.
Ph.D. in physics or electrical engineering regarded as essential.

Candidates for these positions will work with a minimum of supervision

There are also a few positions open at Sylvania's Amherst Laboratory for SPECIALISTS IN COMMUNICATIONS SYSTEMS & SPECIAL CIRCUITS.
While a Ph.D. is desirable, it is not essential.

The Amherst Laboratory is now working with other laboratories in Sylvania's Electronic Systems Division on "Plato"—an AMM system to counter IRBM's.

Please write E. F. Culverhouse

ELECTRONIC SYSTEMS DIVISION

SYLVANIA

SYLVANIA ELECTRIC PRODUCTS INC.

Cayuga Road & Wehrle Drive • Amherst, New York

PERSONNEL PLACEMENT

CLASSIFIED: 25¢ per word, minimum charge $4.25. Use of Box Number counts as 10 additional words. Payment in advance is required.

COPY for classified ads must reach SCIENCE 2 weeks before date of issue (Friday of every week).

DISPLAY: Rates listed below—no charge for Box number. Monthly invoices will be sent on a charge account basis — provided that satisfactory credit is established.

Single insertion	$26.00 per inch
13 times in 1 year	24.00 per inch
26 times in 1 year	23.00 per inch
52 times in 1 year	22.00 per inch

For PROOFS on display ads, copy must reach SCIENCE 4 weeks before date of issue (Friday of every week).

Replies to blind ads should be addressed as follows:
Box (give number)
Science
1515 Massachusetts Ave., NW
Washington 5, D.C.

POSITIONS WANTED

Biochemist, Ph.D.; 3 years, full-time university teaching; 6 years as director of research, well-known institution; recognized as authority in field of steroid analysis. Medical Bureau, Burneice Larson, Director, 900 North Michigan, Chicago. X

Biologist; cellular physiology; microbiology; comparative anatomy. Ph.D. expected August 1958; 27, married. Desires academic or industrial position September 1958. Box 92, SCIENCE. X

Botanist. Ph.D. General botany, mycology-physiology; 1 year of teaching experience in southern university. Desires academic position. Box 89, SCIENCE. X

Comparative Anatomy; embryology; ecology. A.B., M.S., Ph.D. expected February 1959; 28. Desires academic position September 1958 Philadelphia area or New England. Box 88, SCIENCE. X

Medical Entomologist, Parasitologist, 40, Ph.D., C.A.P. and E. (London School of Hygiene and Tropical Medicine). Associate professor in medical school desires teaching and research position in entomology and/or zoology or biology department, medical school, school of public health, or industrial position. Fifteen years of teaching; research in tropical and arctic areas; numerous publications; recipient of many fellowships and research grants. Box 86, SCIENCE. 4/18

Physiologist, fungi, plants; genetics. Ph.D.; 39. Biochemical, tracer, radiobiological, microorganism research. Teaching and administration. Prefers teaching-research location, will consider others. Box 90, SCIENCE. X

Research Director, Director of Pharmacology or equivalent. M.D., 16 years' experience in academic and industrial research in pharmacology; vast number of publications. Considerable experience in directing research. Box 93, SCIENCE. X

Virologist, Ph.D.; successful product development, tissue culture, industrial relocation desired. Box 91, SCIENCE. X

POSITIONS OPEN

Applications are invited for position, beginning September 1958, of **Assistant Professor of Biology** to teach invertebrate zoology. Opportunities for research available. Salary scale $4400–$6000. Appointment not necessarily at bottom of scale. University contributes toward moving expenses. Applications with curriculum vitae and names of three referees and a recent photograph should be sent to the Head, Department of Biology, Memorial University of Newfoundland, St. John's, Newfoundland, Canada. 3/28; 4/4

Assistant Professor of Biochemistry. Ph.D. to conduct research and teach one course to graduate students. Active research department in new building with modern equipment. Salary in accordance with experience. Write to D. B. Johnstone, Department of Agricultural Biochemistry, University of Vermont, Burlington, Vt. X

POSITIONS OPEN

Assistant, Atomic Energy Project, B.S. or M.S., male or female, learn modern biochemical techniques. Philadelphia. Box 85, SCIENCE. X

Biologist-Pharmacologist. Unusual opportunity for aggressive man to head department. Independent research and testing organization. Send résumé to Dr. J. Eibert, Scientific Associates, 3755 Forest Park, St. Louis 8, Missouri. 4/4, 11

(a) **Chief Chemist;** to head busy department, also assume teaching responsibilities; three pathologists head laboratory, 300-bed general hospital; important western university city. (b) **Bacteriologist;** newly created position for qualified B.S., M.S., in private laboratory of two pathologists supervising several area hospital laboratories; to $6000; resort community 30,000, Midwest. (c) **Research Biochemist;** special interest hormones, human reproduction; prefer qualified histochemistry, paper chromatography, electronic instruments; midwestern university medical school; to $7000. (d) **Pharmacologist;** Ph.D. with small animal experience to head animal laboratories, well-established consultant to food, pharmaceutical industries; to $8000, fringe and bonus benefits. (e) **Biochemist;** B.S., M.S., to head section, 250-bed general hospital; to $6000; East. Woodward Medical Bureau, Ann Woodward, Director, 185 North Wabash, Chicago. X

Department of Zoology in the College of Arts and Sciences, Baghdad, Iraq, is in need of a bacteriologist for teaching and research. A Ph.D. in bacteriology is essential, a preference is given to some background in human pathology and teaching experience. Salary according to background of applicant. Box 84, SCIENCE. X

ENDOCRINOLOGIST

Ph.D. or M.D. with 5 to 10 years experience in Endocrinological Research to head Department of Endocrinology in an expanding pharmaceutical organization. This is a key position in a company where real emphasis is placed on research. Liberal benefits. Write to

H. W. Werner
Vice President in Charge of Research
The Wm. S. Merrell Company
Cincinnati 15, Ohio

JOHNSON & JOHNSON
LIMITED

has key positions for

1. BACTERIOLOGIST
2. ORGANIC PHARMACEUTICAL CHEMIST
3. PHYSICAL CHEMIST

Qualifications: M.Sc. or Ph.D. plus experience. Reply to:

Director of Research
7101 Notre Dame St. East
Montreal, Que.

POSITIONS OPEN

Graduate Research Assistantship in Pharmacology; M.S. and chemical background preferred; annual stipend $2400 starting 1 July 1958; eastern metropolitan area. Box 82, SCIENCE, 4/4

Mathematician: Ph.D. preferred. Opportunities in academic and research position. Write to Chairman, Division of the Natural Sciences, Dillard University, New Orleans 22, Louisiana. 3/28; 4/4

Laboratory Technician; bachelors; male or female; biology, chemistry training desirable; concurrent postgraduate work possible. Department of Plant Nematology, University of California, Davis, California. X

Medical Textbooks. Prominent New York City medical publisher offers unusual opportunity in textbook department. Sales, teaching or editorial experience in medical or related field desirable. Full résumé. Replies confidential. Box 94, SCIENCE. X

NEW WORLD-WIDE SUMMER PLACEMENT DIRECTORY. Thousands of opportunities in all states, many foreign lands for science teachers, and so forth, who have the summer free. Includes study awards, industry, camps, resorts, ranches, travel tour agencies, earning free trips to Europe, and so forth. Earn, learn, and travel while you vacation. Complete information, including salaries. Send $2 now. CRUSADE, Sci., Box 99, Station G, Brooklyn 22, N.Y. eow

Pharmacologist, Ph.D. Broad training, industrial research in fields of endocrinology, parasympatholytics, or inflammation. Experience preferred.

Histochemist, Ph.D. Training in histology and biochemistry. Basic investigations on morphology and biochemistry of skin.

Biochemist, Ph.D. Training in physiology and biochemistry. Experience in research on local anesthetics or pain perception.

Location, Chicago. Box 95, SCIENCE. X

Physiologist, Ph.D., to teach undergraduate and graduate courses in southern university. Ample facilities and opportunities for research. Box 87, SCIENCE. 4/11

QUALIFIED PERSONS with a background in organic and analytical chemistry, biochemistry, histology, or zoology needed to fill a number of openings for biochemists and medical research technicians. Positions offer opportunity to work on projects with expert researchers. Liberal benefits are offered in pleasant university atmosphere. Salaries commensurate with ability. For further information contact Personnel Department, University of Michigan, 1020 Administration Building, Ann Arbor, Michigan. X

SENIOR RESEARCH SCIENTIST (PHYSIOLOGY)

Appointment at minimum of $8310 with five annual increments to maximum of $10,020. To do research in neuro-endocrinology in the Neuro-Endocrine Research Unit of Willowbrook State School, Staten Island, N.Y. Knowledge of biologic testing of hormones on rodents and statistical evaluation methods is valuable but not essential. Ph.D. is necessary. Applications to be made to H. H. Berman, M.D., Director, Willowbrook State School, Staten Island 14, N.Y. 4/4, 11

Two new openings in Research Library, Detroit, Michigan, with possibility of transfer to new medical research unit at Ann Arbor, Michigan, in 1960.

1. **Cataloger with thorough background in classification.**
   MLS degree and background in science or science degree.
2. **Reference Librarian**
   Science degree with library background or training.

Applicants should have experience in industry or other special library and ability to assume responsibility for respective functions. French and German required.

Liberal salary and benefit plans.

Send résumé to Personnel Department, Parke, Davis & Company, Detroit 32, Michigan.

POSITIONS OPEN

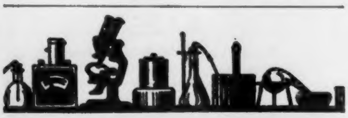
SCIENCE TEACHERS, LIBRARIANS, ADMINISTRATORS urgently needed for positions in many states and foreign lands. Monthly non-fee placement journal since 1952 gives complete job data, salaries. Members' qualifications and vacancies listed free. 1 issue, $1.00. Yearly (12 issues) membership, $5.00. CRUSADE, SCI., Box 99, Station G, Brooklyn 22, N.Y. ew

(a) Scientist with record of accomplishment in synthetic organic chemistry, well-qualified executive; long-established company producing fine chemicals, pharmaceutical intermediates, medical drugs; East. (b) Director, Department of Biological Sciences; duties involve scientific leadership of established group of professional and supporting personnel; should be specialist one of biological sciences, Ph.D. or M.D.; major research organization. (c) Associate Director of Research in charge of pharmaceutical and organic research; key position, one of major pharmaceutical companies; attractive contract; medical school city, Midwest. (d) Biochemist, preferably recently graduated Ph.D. interested in mucopolysaccharides and mucoproteins; association university group studying gastric juice; opportunity faculty post; West. S4-1 Medical Bureau, Burneice Larson, Director, 900 North Michigan Avenue, Chicago. X

Virus Research: M.D. or Ph.D. interested in infectious diseases, basic studies on mechanisms of infection and on etiology, pathogenesis and epidemiology of virus diseases of infancy and childhood. Excellent facilities. Salary and rank open on basis of candidate's qualifications. Starts 1 July 1958. Box 97, SCIENCE. 4/11, 18

FELLOWSHIPS

Fellowship: 2-year tenure, 1 July 1958, for D.V.M. postdoctoral opportunity for training in virus diseases and for research on etiology, pathogenesis and epizootiology of animal diseases. Independent research one-half time. Stipend $5000 per annum, tax exempt. Box 96, SCIENCE. 4/11, 18



The Market Place

BOOKS • SERVICES • SUPPLIES • EQUIPMENT

DISPLAY: Rates listed below—no charge for Box number. Monthly invoices will be sent on a charge account basis — provided that satisfactory credit is established.

Single insertion	$26.00 per inch
13 times in 1 year	24.00 per inch
26 times in 1 year	23.00 per inch
52 times in 1 year	22.00 per inch

For PROOFS on display ads, copy must reach SCIENCE 4 weeks before date of issue (Friday of every week).

SUPPLIES AND EQUIPMENT

albino rats*

Descendants of the Sprague-Dawley and Wistar Strains

•

Hypophysectomized Rats

•

HENRY L. FOSTER, D.V.M.
President and Director
THE CHARLES RIVER BREEDING LABS.
P.O. Box P, Brookline 46, Mass.

• HYPOPHYSECTOMIZED RATS

Shipped to all points via Air Express
For further information write
HORMONE ASSAY LABORATORIES, Inc.
8159 South Spaulding Ave., Chicago 29, Ill.

SUPPLIES AND EQUIPMENT

PURINES C14
and other tagged compounds
OF HIGH RADIOPURITY
Tracerlab ISOTOPES SPECIALTIES COMPANY INC.
P.O. Box 688, Burbank, California

Sprague-Dawley, Inc.
Pioneers in the development of the standard laboratory rat.
Sprague-Dawley, Inc.
P.O. Box 2071, Madison 5, Wisconsin
Phone: CEdar 3-5318

SUPPLIES AND EQUIPMENT

SWISS MICE

Send for booklet

TACONIC FARMS
GERMANTOWN NEW YORK

4 April 1958

Readers' Service
Information Requisition

Use this easy self-mailer to obtain further information

It's simple: Mark — Clip — Fold — Mail

This coupon is for your convenience—to facilitate your requests for further information about advertised products and items in Equipment.

From:

Name .... Position ....

Company ....

Street ....

City .... Zone .... State ....
(Please print or type)

Mark, clip coupon — FOLD HERE along this line — stamp, mail

3¢
STAMP

To:

Readers' Service
SCIENCE MAGAZINE
Room 740
11 West 42 Street
New York 36, New York

Fasten Here Only
Staple, Tape, Glue

PROFESSIONAL SERVICES

TO AUTHORS
seeking a publisher
Learn how we can publish, promote and distribute your book on a professional, dignified basis. All subjects considered. Scholarly and scientific works a specialty. Many successes, one a best seller. Write for booklet SC—its free.
VANTAGE PRESS Inc. • 120 W. 31 St., N.Y. 1
In Calif.: 6253 Hollywood Blvd., Hollywood 28

NDI — COORDINATED RESEARCH — NEW DRUG INSTITUTE
TOXICITY TESTS following FDA procedures, for chemicals, foods, drugs, cosmetics, pesticides, additives. Biological assays. Screening tests. Complete research and development services. No obligation for estimates. Call or write Arthur D. Herrick, Director.
NEW DRUG INSTITUTE
130 East 59 St., New York 22 • Mu 8-0640

SUPPLIES AND EQUIPMENT

MICROSLIDES
Insects, Marine Life, Zoological, Botanical, British Fresh Water Algai
FREE Send for Complete List FREE
ESBE LABORATORY SUPPLIES
459 Bloor St., W.,
Toronto, Ontario, Canada

Kilogram Quantities
OLEIC ACID
METHYL OLEATE
99.5 + % Pure
APPLIED SCIENCE LABORATORIES, INC.
140 N. Barnard St., State College, Pa. • AD 8-6282

4 April 1958

Readers Service

Information Requisition

Use this easy self-mailer to obtain further information about items or literature from the Equipment section as well as from advertised products.

EQUIPMENT

Circle below desired number corresponding to:

S972 S975 S977 S978 S981 S982
S983 S984 S985 S986 S987

ADVERTISERS IN THIS ISSUE

Check page number in list below of advertiser from whom you would like more information. If more than one item appears in ad, letters (A, B, C, etc.) are used to indicate particular items available in order of appearance in advertisement. Where more than one ad appears on a page, **"U" indicates upper ad, "L" lower ad, "I" inside ad, "M" middle ad,** and **"O" outside ad.** Advertisements in Personnel Placement and Market Place are not keyed. A multiplicity of items is indicated by *. Readers are requested to specify on this coupon the particular item in which they are interested; otherwise, the request cannot be processed.

☐ 723* ☐ 724 ☐ 725 ☐ 726* ☐ 763UI
☐ 763LI ☐ 7630 ☐ 764UO ☐ 764LO ☐ 765
☐ 766UO ☐ 767, A ☐ 767, B ☐ 769 ☐ 775, A
☐ 775, B ☐ 776

SUPPLIES AND EQUIPMENT

CHERRY HILL FARMS
RATS
MICE
RABBITS
GUINEA PIGS
P.O. BOX 840 CAMDEN, N.J.

BOOKS AND MAGAZINES

Your sets and files of scientific journals
are needed by our library and institutional customers. Please send us lists and description of periodical files you are willing to sell at high market prices. Write Dept. A3S, CANNER'S, Inc.
Boston 20, Massachusetts

THE SCIENTIFIC MONTHLY
October 1915-December 1957
Available Issues
$0.75 per copy • $7.50 per year
SPECIAL OFFER
10 copies of one issue .. $ 6.00
50 copies of one issue .. $25.00
Postage included in all prices
AAAS
1515 Mass. Ave. NW, Washington 5, D.C.

ADVANCES IN EXPERIMENTAL CARIES RESEARCH
AAAS SYMPOSIUM VOLUME
June 1955
246 pp., 6" x 9", 49 illus., index, clothbound
Price $6.75; cash order price for AAAS members **$5.75**

". . . This is a real contribution to dental science. It is the most comprehensive review of animal experimentation on caries ever attempted. The format and reproduction of illustrations are excellent.

"This compilation of research findings should have wide circulation and should be a storehouse of information for all those who are investigating the problem of dental caries. It should serve to clarify the thinking and prevent useless duplication in future studies. . . ."

Russell W. Bunting, School of Dentistry, University of Michigan.

AAAS, 1515 Mass. Ave., NW, Washington 5, D.C.

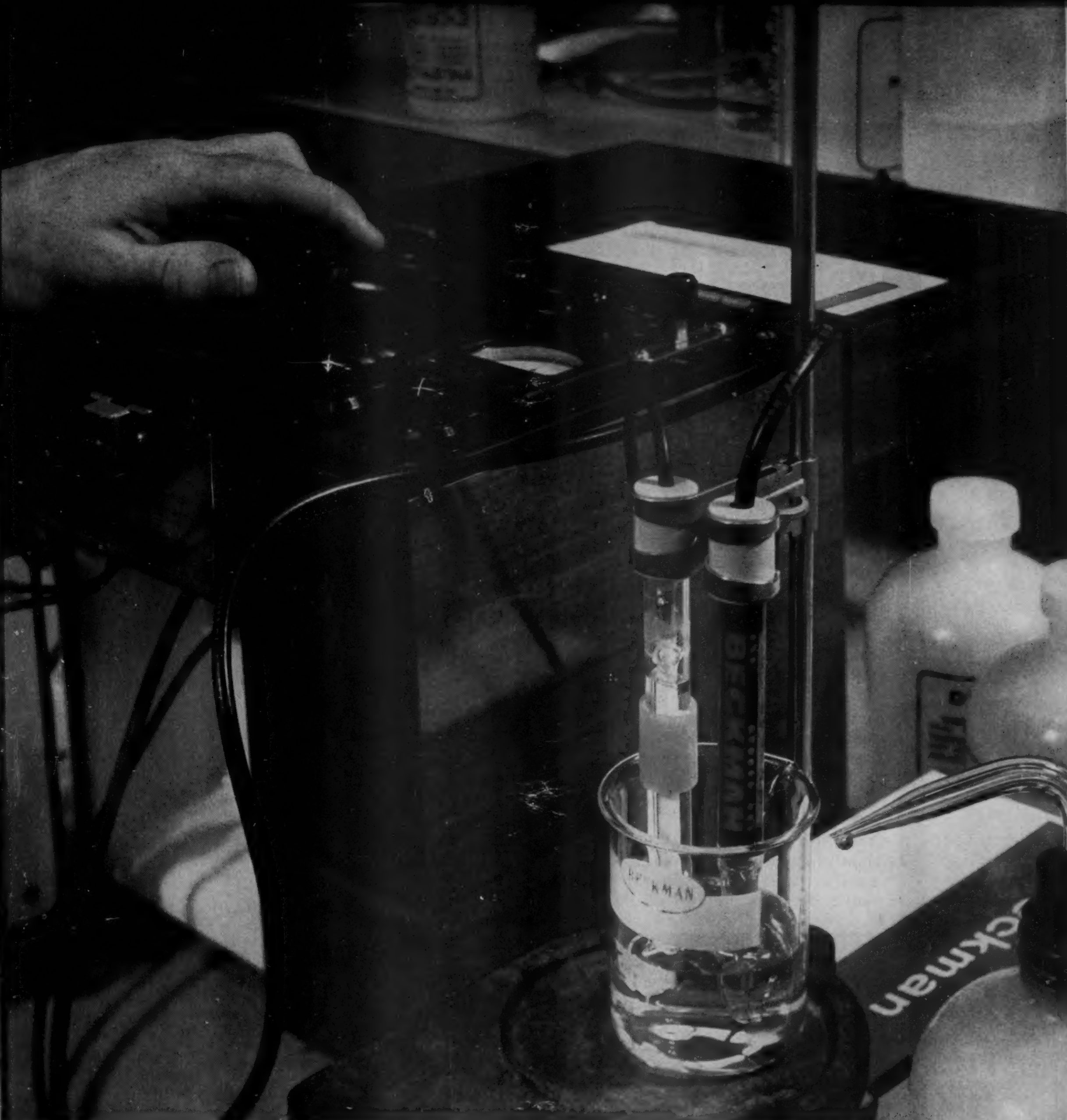


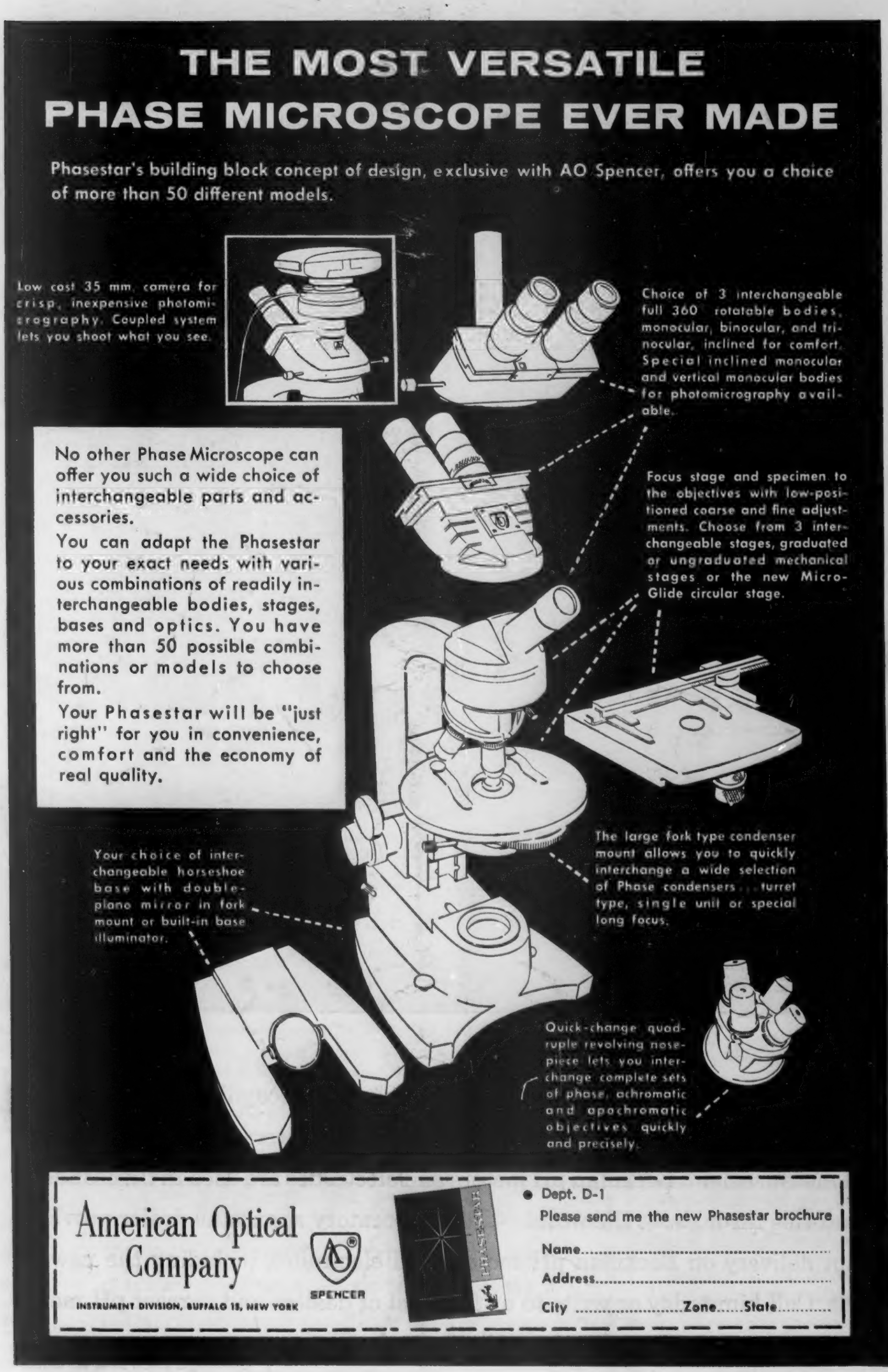
PHOTO BY WILL CONNELL

You'd know them anywhere. Beckman pH electrodes...recognized as the finest... and Beckman's Model G pH Meter...described in the literature as the standard of pH measurement. Beckman pH meters and electrodes are used in thousands of laboratories throughout the world. ¤ Your laboratory apparatus dealer provides prompt delivery on Beckman pH meters and electrodes, including the newest models. Call him today or write to us for a list of dealers and current pH meter information. Ask for Data File L-41-38.

Beckman®

Scientific Instruments Division
2500 Fullerton Road, Fullerton, California
a division of Beckman Instruments, Inc.

ULTRAVIOLET AND INFRARED SPECTROPHOTOMETERS • GAS CHROMATOGRAPHS • pH METERS • ELECTROCHEMICAL INSTRUMENTS
SALES AND SERVICE FACILITIES ARE MAINTAINED BY BECKMAN/INTERNATIONAL DIVISION IN FIFTY COUNTRIES


THE MOST VERSATILE PHASE MICROSCOPE EVER MADE
Phasestar's building block concept of design, exclusive with AO Spencer, offers you a choice of more than 50 different models.
Low cost 35 mm. camera for crisp, inexpensive photomicrography. Coupled system lets you shoot what you see.
Choice of 3 interchangeable full 360° rotatable bodies, monocular, binocular, and trinocular, inclined for comfort. Special inclined monocular and vertical monocular bodies for photomicrography available.
No other Phase Microscope can offer you such a wide choice of interchangeable parts and accessories.
You can adapt the Phasestar to your exact needs with various combinations of readily interchangeable bodies, stages, bases and optics. You have more than 50 possible combinations or models to choose from.
Your Phasestar will be "just right" for you in convenience, comfort and the economy of real quality.
Focus stage and specimen to the objectives with low-positioned coarse and fine adjustments. Choose from 3 interchangeable stages, graduated or ungraduated mechanical stages or the new Micro-Glide circular stage.
Your choice of interchangeable horseshoe base with double-plano mirror in fork mount or built-in base illuminator.
The large fork type condenser mount allows you to quickly interchange a wide selection of Phase condensers ... turret type, single unit or special long focus.
Quick-change quadruple revolving nosepiece lets you interchange complete sets of phase, achromatic and apochromatic objectives quickly and precisely.
American Optical Company
INSTRUMENT DIVISION, BUFFALO 15, NEW YORK
AO SPENCER
PHASESTAR
Dept. D-1
Please send me the new Phasestar brochure
Name
Address
City Zone State